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Retroactive Inhibition as Affected by Conditions of Learning

BY

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CHAPTER I

INTRODUCTION AND HISTORY OF PROBLEM

Previous experimental investigations of retroactive inhibition have come to contradictory conclusions. Müller and Pilzecker[1] and Heine[2] found what they believed to be decided evidence for retroactive inhibition. De Camp,[3] on the other hand, found little or no evidence for it.

The present investigation, though undertaken from a different point of view, may throw some light upon this contradiction. At any rate, it has discovered that, in the case of certain contrasted conditions of learning, the one condition may show decided evidence for retroactive inhibition, while another contrasted condition shows little or no evidence for it.

Previous Investigations

Before proceeding to a statement of our special methods and results, we may briefly summarize the previous work.

Müller and Pilzecker

To Müller and Pilzecker we first owe the concept of retroactive inhibition. They presented a series of experiments specifically designed to show that the introduction of enforced mental activity immediately succeeding the learning of a list, exerts an inhibitory effect upon the later memory for that list. This they established, not only by the use of their own method of Right Associates (Treffermethode), but also by that of the Ebbinghaus[4] or Müller and Schumann[5] Savings method (Ersparnismethode).

With the method of Right Associates they performed five experiments. We may briefly epitomize the conditions.

---

[1] Müller, G. E., and Pilzecker, A. Zeitschrift für Psychologie, Ergänzungsband I. 1900.

[2] Heine, R. Zeitschrift für Psychologie 68, 1914, pp. 161-236.

[3] De Camp, J. E. Psychological Monographs, Vol. XIX, 1915. No. 4.

[4] Ebbinghaus, H. Über das Gedächtnis, Leipzig, 1885.

[5] Müller, G. E., and Schumann, F. Zeitschrift für Psychologie, 6, 1893-4, pp. 81-190 and 257-339.

In the case of each experiment the results were compared for two sets of lists. These differed only as to the manner in which the interval between learning and test was filled. For the one set of lists (Hauptreihen), some form of mental activity, "work," such as learning another list or studying pictures (Aussage test) was enforced upon the subject immediately after learning. For the other set of lists (Vergleichreihen), the interval between learning and test was left entirely free.

The exact conditions and the results we have summarized in

TABLE I.

		TL	Interval	R	*r*	T*r*
Exp. 31 (a) (n=144)	V	6 min.	: Rest 6 min.	8	48	2480
Subject Frau P	H	7min. 43.2sec.	: Rest 34.4 sec.; Ll 68.8 sec.; Rest 6 min.	8	23	3570
Exp. 31 (b) (n=72)	V	24 hrs.	: Rest followed by usual activities.	16	36	3460
	H	24 hrs.	: Rest 1 min.; Ll 2 min. 17.6 sec.; usual activities.	16	22	3660
Exp. 32 (n=162)	V	8 min.	: Rest 8 min.	12	55	3070
Subject Dr. Behrens	H	10min. 4.6sec.	: Rest 17.8 sec.; Ll 1 min. 46.8 sec.; Rest 8 min.	12	27	3230
Exp. 33 (n=72)	V	8 min.	: Rest 8 min.	6	72	2090
Subject Frau M	H	9 min. 39 sec.	: Rest 27 sec.; Ll 1 min 12 sec.; Rest 8 min.	6	43	2260
Exp. 34 (n=144) Subject	H_2	1.5 hrs.	: Rest 6 min.; Ll 1 min. 48 sec.; Rest 10 min., followed by other activities.	12	49	3000
Frau P.	H_1	1.5 hrs.	: Rest 17.2 sec.; Ll 1 min. 48 sec.; Rest 10 min., followed by other activities.	12	28	2760
Exp. 35 (n=108)	V	8 min.	: Rest 8 min.	8	56	2490
Subject Dr. Behrens	H	8 min.	: Asge. 2 min.; Rest 6 min.	8	24	2950

Table I. H stands for Hauptreihen, V for Vergleichreihen, n for the total number of syllable-pairs in each kind. Under "Interval" are given the duration and disposition of the time between learning and test. TL gives the total length of the interval. Ll stands for learning another similar list, Asge for Aussage experiment. R stands for the number of repetitions given in the original learning; *r* for the percentum of successes; and T*r* for the average response time for the successes.

Experiment 34 alone needs special mention. In this experiment the two sets of lists compared are both followed by work, but for the one set, the H_1 lists, the work followed immediately (in 17.2 sec.), while for the other, the H_2 lists, it followed only after 6 minutes.

The table shows that in the case of all five experiments there appeared to be greater inhibition for the lists followed immediately by work than for those followed immediately by rest.

We turn now to experiments in which the Savings method

TABLE II.

		TL		Interval	R	Rel
Exp. 36(a) (n=8) Subject	V	½ hr. or more depending on order of lists	:	Rest 4 min.; Other lists and rests; Rest 10 min.	5	11.25
Frl. Brinkman	H	"	:	Ll (another list completely learned); Rest 4 min.; Other lists and rests; Rest 10 min.	5	13.0
Exp. 36(b) (n=32) Subject	V	15 min. or more depending on order of lists	:	Rest 4 min.; Other lists and rests; Rest 5 min.	4	6.6
Frl. Brinkman	H	"	:	Ll 1 min. 20 sec.; Rest 4 min.; Other lists and rests; Rest 5 min.	4	7.8
Exp. 37 (n=24) Subject	V	15 min. or more depending on order of lists	:	Rest 4 min.; Other lists and rests; Rest 5 min.	5	4.9
Frau P.	H	"	:	Asge 2 min.; Rest 4 min.; Other lists and rests; Rest 5 min.	5	8.0

was used. Table II presents the conditions and results. Rel. stands for average number of repetitions required in the relearning. n now stands for the number of *lists* of each kind.

These experiments also show greater inhibition for the H lists.

Heine

The primary object of her experiments was to determine whether or not retroactive inhibition plays the same part for recognition memory that Müller and Pilzecker had established for it in connection with recall memory. Nineteen experiments using the Recognition method were performed. In not one of these was evidence of inhibition found. In addition, however, to these nineteen experiments using the Recognition method, fourteen others, using either the Right Associates method or the Savings method, were performed to see, in the first instance, if the results of Müller and Pilzecker would be substantiated, and later to see if some additional laws might be added.

The conditions of the first four of these fourteen experiments were almost identical with those of the Müller and Pilzecker experiments. See Table III.

TABLE III.

		TL		Interval	R	*r*	T*r*
Exp. 13 (n=126)	V	8 min.	:	Rest 8 min.	8	17.5	2445
Subject R	H	8 min.	:	Asge 2 min. Rest 6 min.	8	6.4	3503
Exp. 14 (n=108)	V	8 min.	:	Rest 8 min.	10	57.4	1395
Subject Sch	H	8 min.	:	Asge 2 min. Rest 6 min.	10	36.1	1557
Exp. 15 (n=72)	V	1.5 hrs.	:	Rest 6 min., other activities.	12	36.1	2450
Subject Bl	H	1.5 hrs.	:	Ln 4 min., other activities.	12	9.7	2837
Exp. 16 (n=84)	V	24 hrs.	:	Rest 6 min., other activities.	15	37.7	2123
Subject M	H	24 hrs.	:	Ln 4 min., other activities.	15	35.4	2987

In experiments 15 and 16, the work consisted in learning a list of eight four-place numbers (Ln). The other symbols are the same as for previous tables.[6]

It will be observed that all four experiments gave definite evidence of inhibition.

We turn now to five experiments performed by Heine to discover whether retroactive inhibition plays a part not only as regards association between successive syllables, but also as regards associations within the single syllable. To test this question, a procedure similar to the preceding was adopted, save that the final test consisted in the presentation of two letters of each syllable, and asking for the third letter, instead of in the presentation of the first syllable of each pair, and asking for the second syllable.

The individual conditions and the results have been summarized in Table IV.

TABLE IV.

		TL		Interval	R	*r*	T*r*
Exp. 17 (n=216)	V	9 min.	:	Rest 9 min.	8	48.6	2799
Subject D	H	9 min.	:	Ln 3 min., Rest 6 min.	8	35.2	3443
Exp. 18 (n=216)	V	9 min.	:	Rest 9 min.	12	37.7	1993
Subject R	H	9 min.	:	Ln 3 min., Rest 6 min.	12	27.6	2940
Exp. 19 (n=216)	V	9 min.	:	Rest 9 min.	8	73.6	1707
Subject S	H	9 min.	:	Ln 3 min., Rest 6 min.	8	56.9	1993
Exp. 20 (n=144)	V	9 min.	:	Rest 9 min.	10	32.7	3935
Subject Scho	H	9 min.	:	Ln 3 min., Rest 6 min.	10	15.9	5601
Exp. 21 (n=216)	V	9 min.	:	Rest 9 min.	12	47.7	3784
Subject R	H	9 min.	:	Ln 3 min., Rest 6 min.	12	38.0	4237

---

[6] When the Savings method is used n stands for the number of *lists* in each group; where the Right Associates method is used, for the number of *syllable pairs* in each group.

We observe a decided effect of inhibition in each of the five experiments.

In the last five of the fourteen experiments the author seeks to discover if strongly impressed associations are relatively less affected by retroactive inhibition than are weak ones.

In the first one of these last five experiments the method of Right Associates was used as in the previous experiments, but in each hour four lists were learned: an H and a V list, and an h and a v list. The H and the V lists differed from the h and the v lists only in that they were given a greater number of repetitions in the original impression, and were recalled after a longer interval than the h and v lists. The other conditions and the results are shown in Table V.

TABLE V.

		TL		Interval	R varied from	*r*	T*r*
	V	24 hrs.	:	Rest 9-10 min.	30-20	62.0	2406
Exp. 29	H	24 hrs.	:	Ln 3 min., Rest 6-7 min.	30-20	36.2	3013
(n=108)							
Subject Rot							
	v	9 min.	:	Rest 9 min.	6-2	70.4	1939
	h	9 min.	:	Ln 3 min., Rest 6 min.	6-2	21.1	2683

The expected result appears. While the *r* for the v list is distinctly bigger than that for the V lists, the *r* for the h lists is smaller than for the H lists.

In the two next experiments the author employed not the Right Associates method but the Savings method. In these two experiments also there were V, H, v, and h lists. The v and h lists were given a small number of repetitions in the original learning, the V and H lists a large number. After an equal interval of time all four lists were relearned.

The results appear in Table VI.

R stands for the numbers of repetitions in the original learnings. Rel stands for the numbers of repetitions in the relearnings; the figures outside the brackets are means, those within the brackets medians.

TABLE VI.

		TL		Interval	R	Rel
	V	1.5 hrs.	:	Rest and other activities.	8	25.2 (26.5)
Exp. 30	H	1.5 hrs.	:	Ln 3 min. Rest, other activities.	8	25.2 (24.0)
(n=24)						
Subject Ruv	v	1.5 hrs.	:	Rest and other activities.	4	21.2 (21.5)
	h	1.5 hrs.	:	Ln 3 min. Rest, other activities.	4	22.0 (23.0)
	V	1.5 hrs.	:	Rest and other activities.	12	24.2 (24.0)
Exp. 31	H	1.5 hrs.	:	Ln 3 min. Rest, other activities.	12	25.3 (25.0)
(n=24)						
Subject R	v	1.5 hrs.	:	Rest and other activities.	6	20.3 (19.5)
	h	1.5 hrs.	:	Ln 3 min. Rest, other activities.	6	22.5 (23.0)

Again we note a bigger inhibition for the h lists than for the H lists.

In her last two experiments the author returned to the method of Right Associates. The experiments were performed on two subjects who had given evidence of inhibition in two of the earlier experiments. Here these same two subjects were given a greater number of repetitions. For the sake of comparison, Table VII gives the results both for the two earlier experiments and for the two new ones.

TABLE VII.

		TL		Interval	R	*r*	T*r*
Exp. 32	V	0.5 hrs.	:	Rest.	25	22.2	5955
(n=144)							
Subject R	H	0.5 hrs.	:	Pictures 3 min. Rest.	25	20.2	5161
Exp. 13	V	8 min.	:	Rest 8 min.	8	17.5	2445
(n=126)							
Subject R	H	8 min.	:	Asge 2 min. Rest 6 min.	8	6.4	3503
Exp. 33	V	24 hrs.	:	Rest.	25	11.1	2030
(n=72)							
Subject Sch	H	24 hrs.	:	Pictures 3 min. Rest.	25	16.7	1946
Exp. 14	V	8 min.	:	Rest 8 min.	10	57.4	1395
(n=108)							
Subject Sch	H	8 min.	:	Asge 2 min. Rest 6 min.	10	36.1	1557

Again we find less inhibition in the case of the more strongly impressed associations.

Summing together the results of Heine's fourteen experiments, we can conclude that they seem pretty definitely to substantiate the findings of Müller and Pilzecker as regards retroactive inhibition, and that they indicate a greater degree of such inhibition for the more weakly impressed associations.

Let us now turn to De Camp's findings. We shall see that they contradict those of Müller and Pilzecker and of Heine.

De Camp

This author started with the assumption that the existence of retroactive inhibition had been definitely demonstrated by Müller and Pilzecker,[7] and sought to determine the relative degrees of such inhibition produced by various amounts and different distributions of work. He obtained results, however, which ultimately led him to doubt the experimental importance of retroactive inhibition under *any* conditions. We will present a brief review of his experiments, but for convenience's sake will take them up in somewhat different order from that in which he himself presents them.

First we will consider a group of experiments in which the conditions are very similar to those of Müller and Pilzecker and of Heine.

As work in most of these experiments multiplication was used. In one experiment, however, physical (ergographic) work was used; in a second, problem solving; and in a third, chess-playing. In one experiment the syllables were presented auditorily instead of visually. The results are presented in Table VIII. The caption "work," unless otherwise designated, means multiplication.

Examining the table, we find four out of the seven experiments in which both *r* values and times indicate inhibition. In two of the others (Experiments VII-VIII) the *r* values are for

---

[7] De Camp seems to have missed the final report of Fraulein Heine's work, and to have been acquainted only with the abbreviated report presented by Prof. G. E. Müller at the V. Kongress für experimentelle Psychologie, in Berlin, 1912.

TABLE VIII.

		Interval	R	*r*†	T*r*
Subject B					
Exp. III	V	Rest 15 min.	10	48	2221
(n=112)	H	Work 10 min., Rest 5 min.	10	33	2673
Subject D					
Exp. V	V	Rest 15 min.	10	34	5149
(n=70)	H	Work 15 min.	10	30	5822
Subject W					
Exp. VI	V	Rest 15 min.	10	79	2828
(n=63)	H	Work 10 min., Rest 5 min.	10	68	2955
Subject W					
Exp. VII Auditory	V	Rest 15 min.	6	41	5127
(n=70) presentation	H	Work 10 min., Rest 5 min.	6	40	4286
Subject D					
Exp. VIII*	V	Rest 16 min.	10	67	4862
(n=63)	H	Adj. 1 min., Erg. 10 min., Rest 5 min.	10	43	4108
Subject Z B					
Exp. IX (b)	V	Rest 15 min.	10	53.6	5238
(n=56)	H	Solving problems 6 min., Rest 9 min.	10	46.4	5593
Subject P					
Exp. XI	V	Rest 15 min.	8	40	2343
(n=70)	H	Chess 10 min., Rest 5 min.	8	50	2392

*It was in this experiment that ergographic work was substituted for mental work. One minute was required for adjusting the ergograph. This was followed by ten minutes work with the instrument. The subject was harnessed so that he lifted the weight from the shoulders.

†The original monograph gives the total numbers of correctly recalled syllables, the numbers of partially correct syllables, and the averages, medians, and mean variations for the completely correct syllables, in addition to *r*, the percentages of completely correct syllables. For comparison with the results of Müller and Pilzecker and of Heine as given by them, we here present the *r* values only.

inhibition, but the times are against it. In the third (Exp. XI) *r* values are against inhibition but times are for it. We conclude that these seven experiments, taken as a whole, do not give nearly the same evidence for inhibition as did the similar experiments of Müller and Pilzecker and of Heine.

In each of the next four experiments to be considered, a large number of different distributions of rest and work were examined. In the first two of these four, the fifteen minute interval between learning and test was distributed in 16 different ways: Rest 15, Work 0; Rest 14, Work 1; Rest 13, Work 2; Rest 12, Work 3; etc.—to Rest 0, Work 15. The Rest always preceded the Work. In the last two of the four experiments, the last nine minutes of the total 15 were spent in rest, but the first 6 minutes suffered different distributions, as follows: Rest 0, Work 6, Rest 9; Rest 1, Work 5, Rest 9; Rest 2, Work 4, Rest 9; etc.—to Rest 6, Work 0, Rest 9. It is to be noted that for both sets of distributions there was only one form in which the Work followed immediately after the learning, viz., Rest 0, Work 15; and Rest 0, Work 6, Rest 9. We will compare the results for these two distributions, in which work follows immediately and for which it would seem that inhibition, if it appears at all, should be a maximum, with the distributions in which there was no work, but complete rest. The comparison is given in Table IX.

Examining Table IX, we note that the *r* values indicate inhibition in only one experiment, the T*r* values in two experiments. The evidence certainly seems to be quite as strongly against inhibition as in favor of it.

We may quote, finally, three other experiments performed by De Camp in which similar results were obtained. In the first of the three (Exp. IV), two distributions of the form Rest 6. Work 9 and Rest 2, Work 13 were examined. In the third (Exp. XIII), the Reconstruction method was used. The memory test consisted in this case in trying to reconstruct an arrangement of five chessmen which had been exposed for 15 seconds three minutes before. The work consisted in arithmetic. For the results and further conditions of all three experiments, see Table X. In the case of experiment 13, the average number of

TABLE IX.*

		Interval	R	*r*	T*r*
Exp. I (n=28)	V	Rest 15 min.	16	18	2250†
Subject B	H	Rest 0 min., Work 15 min.	16	18	4250†
Exp. II (n=56)	V	Rest 15 min.	16	50	6700†
Subject F	H	Rest 0 min., Work 15 min.	16	55	6850†
Exp. IX(a) (n=140)	V	Rest 15 min.	10	41	6349
Subject Z B	H	Rest 0 min., Work 6 min., Rest 9 min.	10	31	4669
Exp. X (n=42)	V	Rest 15 min.	10	33	2500
Subject A	H	Rest 0 min., Work 6 min., Rest 9 min.	10	36	1249

misplacements per test is given under the caption "errors," and the average number of seconds required for the reconstruction under that of "time." n in the case of this experiment represents the number of tests made.

TABLE X.

		Interval	R	*r*	T*r*
Exp. IV (n=70)	H_1	Rest 6 min., Work 9 min.	10	29	2675
Subject B	H_2	Rest 2 min., Work 13 min.	10	37	3328
Exp. XII (n=14 per subject)	V	Rest 15 min.	12	42.5	2047
34 Subjects	H	Solving problems 6 min., Rest 9 min.	12	42.0	2184
			Errors		*Time*
Exp. XIII (n=36)	V	Rest 3 min.	10.4		67.4 secs.
Subject Z B	H	Arithmetic 2 min., Rest 1 min.	11.7		66.2 secs.

---

*A number of the figures given in this table and the next were not presented as such in De Camp's text, but have been computed by the writer from values that were given, or from plots.

†Approximate, estimated as accurately as possible from plot given in text.

It will be observed again that no one of the three experiments gives certain evidence of inhibition and that experiment IV seems to point decisively in the opposite direction.

Summing up the total results of De Camp's fourteen experiments, we must conclude with him that they afford no such clear evidence for inhibition as that afforded by the results of Müller and Pilzecker and of Heine.

Let us now turn to our own experiments.

CHAPTER II

PLAN OF INVESTIGATION

These experiments, like those of De Camp, started with the supposition that retroactive inhibition had been definitely established.[1] They originated with the idea that lists made up of numbers and *indifferent* words (i.e., words of indifferent meaning) might be more affected by retroactive inhibition than lists made up of numbers and *pleasant* words. In testing this possibility, results were obtained similar to those of De Camp, in so far as little evidence of inhibition was found. But what evidence there was was always on the side of more inhibition for the *indifferent* lists and less for the *pleasant* lists. This result seemed significant, and it occurred to us to look for another pair of contrasted conditions which might operate in the same sense as pleasantness and indifference, but with more certainty. Our first attempt at finding such a pair led to an experiment in which learning with *normal attention* was contrasted with learning with *artificially distracted attention.* The results were disappointing. Retroactive inhibition was not found for either kind of attention. Two further pairs of contrasted conditions were tried. The results in these cases were successful. Lists learned under *caffeine* were found to be less affected by retroactive inhibition than those learned *without caffeine.* Lists learned in the morning *(efficient hour)* were found to be less affected by inhibition than lists learned in the evening or directly after the noonday meal *(inefficient hour).*

We turn to a presentation of technique.

---

[1] They were begun before De Camp's results were published. They were performed during the summer vacations of 1914, 1915, and 1916 and in the winter semester of 1915-1916.

CHAPTER III

TECHNIQUE

I. Apparatus.

A Hipp chronoscope was not available to measure response times (Trefferzeiten).[1] In the earlier experiments these times were, therefore, not measured. In later experiments, however, a stop watch with an electric magnet for starting and stopping was used. The magnet was connected in one circuit with the falling shutter, and in another with the lip key.

Two styles of lip key were used: In the one style (A), the contacts were so arranged that the opening of the key *made* the circuit. This key when used was connected directly into the magnet circuit. In the other style (B), the opening of the key *broke* the circuit. This key, therefore, when used was connected into the magnet circuit through a relay.

The apparatus for presenting the lists differed for different experiments. In some it consisted of a Rupp-Lipmann Gedächtnisapparat;[2] in others of a kymograph drum connected by pulleys and belts with a 110 V D. C. motor; and in one experiment of a kymograph drum connected with a gravity motor.[3] The Rupp-Lipmann apparatus presented the material in step-wise fashion, i.e., the drum stopped moving for an instant when the syllable reached the middle of the exposure slit. The kymograph drums, on the other hand, revolved continuously.

The speeds of the Rupp-Lipmann apparatus and the gravity motor were absolutely constant. That of the electric motor, on the other hand, although fairly constant throughout any one working hour, varied from one working hour to the next by as much as 2 seconds per revolution of the kymograph drum.

---

[1] The method of right associates (Treffermethode) was used throughout.

[2] Made by Max Marx, Berlin. Loaned from the Harvard Psychological Laboratory by the kindness of Prof. H. S. Langfeld to whom the writer's thanks are due.

[3] Also loaned by the Harvard Laboratory.

II. Construction of Lists, and of Material for "Work."

(A) Word-lists and Number-lists used in Pleasant vs. Indifferent Experiments. (Exps. 1, 2, 3, and 4.)

The complete stock of words from which the words for these lists were drawn consisted of two- and three-syllable adjectives and nouns. The pleasantness or indifference of the individual words in this stock had been subjected to the judgment of a number of individuals. In Experiment 1, the writer alone had passed judgment, and determined which words should go in the pleasant lists and which in the indifferent. In all the other experiments, however, several persons had judged the words.

In the case of the all-word lists (used in some subsidiary experiments performed in connection with the main experiments), the two- and three-syllable words were alternated.

In the number-word lists, the numbers were alternated with the words, the two- and three-syllable words occurring in a specific order. In Experiment 1, the same words which had been used in the all-word lists of the prior subsidiary experiment were used over again in the number-word lists of the main experiment. In Experiment 2, *some* of the same words were used over again. In Experiments 3 and 4, none of the words used in the subsidiary experiments were used in the main experiments.

The numbers used in the number-word lists were in Experiment 2, two-place, in Experiments 1, 3, and 4, three-place. The two-place ones were drawn from a stock consisting of the numbers between 21 and 98 inclusive, with the omission of those ending in 0, and of those in which the same digit appears twice; the three-place ones from a stock consisting of the numbers between 123 and 987 inclusive, with the omission of those containing 0, of those containing the digit 1 in the second place and of those in which the same digit appears twice.

In constructing the lists, the numbers were drawn by chance with the following restrictions:

(a) Two numbers containing the same digit in the same place, such as 348 and 745, or 63 and 65, were always separated in any one list by at least two intervening numbers.

(b) In the case of the lists which were used in the same experiment hour, the number of times in which the digit 1 appeared was made the same in every list.

(c) In using the two-place numbers, the same number was never repeated in the same experiment hour. In using the three-place numbers, the same number was not repeated at all during the course of the experiment.

(B) Nonsense Syllable Lists. (Exps. 6, 7, 8, 9, 10, 11, 12, and 13.)

These were constructed according to the Müller and Schumann rules of "verschärfte Normalreihen,"[4] but using English consonant and vowel combinations instead of German ones. All syllables which were the same as actual words, either in spelling or in pronunciation, were rejected.[5] As initial consonants were used b, d, f, g (pronounced as in "gain"), h, j (pronounced as in "jewel"), k, l, m, n, p, r, s, t, v, w, z, and sh; as terminal consonants, b, d, f, g (pronounced as in "dog"), k, l, m, n, p, s, t, v, z, sh, and ch; and as vowels, ā, ă, ē, ĕ, ī, ĭ, ō, ŏ, ū, ŭ and the two diphthongs ōū (pronounced as in "house"), and oĭ (pronounced as oy in "boy"). The diacritical marks were always given.

(C) Mixed Nonsense Syllable-Word Lists. (Exp. 5.)

These lists were made up by alternating nonsense syllables with one-syllable English words. The nonsense syllables were taken directly from a "verschärft normal" series constructed as just described, the words from some "normal" word-lists.[6] In alternating the syllables and the words, the following prescriptions were used:

(a) No word or nonsense syllable was allowed to have the same vowel sound, the same initial consonant sound, or the same terminal consonant sound, as the immediately preceding or the immediately succeeding nonsense syllable or word.

(b) No word or nonsense syllable was allowed to begin with the same consonant sound that the preceding nonsense syllable or word ended with; and vice versa, no word or nonsense syllable was allowed to end with the same consonant sound that the preceding nonsense syllable or word began with.

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[4] Müller and Schumann, op. cit., p. 106.

[5] Müller and Schumann did not eliminate single syllables which spelled words, but merely syllable combinations, such as "gib nur," or "weib lich," which spelled words or phrases. The relatively greater number of monosyllabic words in English as compared with German made our further restriction necessary.

[6] These one-syllable word lists had been made up for use in other experiments according to rules very similar to those for "Normalreihen."

(D) Material Used after Learning of Lists to Produce Inhibition.

As an activity following immediately after the learning, and intended to produce retroactive inhibition, we used, as did Fraulein Heine,[7] the learning either of tables of numbers or of tables of colored consonants. These tables were constructed in the same manner in which hers were.

III. Methods of Procedure and of Presentation of Data; Subjects.

For convenience, we may speak of learning of *pleasant* lists, learning under *caffeine,* and learning in an *efficient hour* of the day, under the single head of "More Stimulating" learning (M), and learning of *indifferent* lists, learning *without caffeine,* and learning in an *inefficient hour,* under the contrasted head of "Less Stimulating" learning (L).[8]

The method of Right Associates (Treffermethode) has been used throughout. In each experiment four sets of lists were learned: two under the M condition, and two under the L condition. Of the two sets learned under either one of these two conditions, one set consisted of "passive" lists. For these the entire interval between learning and test was left unoccupied, and the subject was instructed to remain as mentally "passive" as possible, and not to think of the lists. The other set consisted of "work" lists. These were followed immediately by a two or three minutes memorizing of numbers or consonants. In the latter part of the interval, between learning and test, the subject remained passive.

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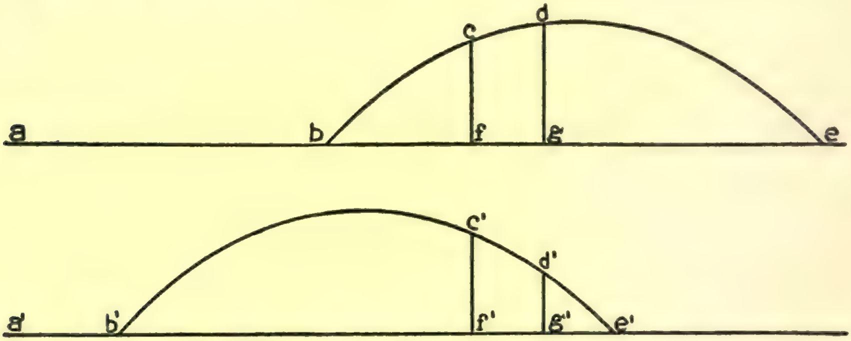
[7] Op cit., pp. 172, 179.

[8] We are primarily justified in grouping the three contrasts under this single head because we are to find that they act similarly with regard to retroactive inhibition. The particular names "More" and "Less Stimulating" were chosen, however, on the basis of other common characteristics aside from that of similarity as to inhibition. It will be shown that the "More Stimulating" conditions seemed to require fewer repetitions for the same degree of learning; that, in the cases of with caffeine vs. without caffeine and of efficient hour vs. inefficient hour, they produced more "work"; and, finally, that the average times of the correct responses were shorter for them than for the "Less Stimulating" conditions. Hence the choice of the terms "More" and "Less Stimulating."

In order that the results of these four sets of lists, which we may term the P and W (M condition), and the p and w (L condition), respectively, may indicate conclusively that the L condition was more affected by retroactive inhibition than the M condition, one definite prescription must be fulfilled. Not only must the difference (r[9] for p lists)—(r for w lists), be greater than the difference (r for P lists)—(r for W lists), but also r for the p lists must itself be equal to or greater than that for the P lists, while that for the w lists must be smaller than, or no greater than, that for the W lists. The following reasoning makes this clear.[10]



Let the curve bcde represent, at the time of testing, the distribution of association strengths for passive lists of the M condition. The abscissae will stand for association strengths, the ordinates for the frequencies of these strengths. Let distance af represent the threshold. The size of area fce will thus measure the percentage of correct responses, (i.e., r) for the P lists. Let the association strengths for the Work lists of the M condition have a similar distribution, save that the entire curve may be considered shoved to the left, nearer the origin. (This assumes, of course, that work will exert an inhibitory effect, and that the amount of this effect will be approximately equal for associations of different absolute strengths.) We may represent this displacement of the work curve as equal to the distance fg. Or, in other words, we may let area gde represent the percentage of correct responses (i.e., *r*) for the W lists. It follows, then, that area fcdg may represent the drop in *r* from the P lists to the W lists or (*r* for P lists)—(*r* for W lists).

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[9] Following the precedent of Müller and Pilzecker, we have let r designate the percentage of correct responses.

[10] This discussion is taken from Heine, op. cit., pp. 212-215.

Turn now to the case of the lists for the L condition. Let us assume that the form of distribution is the same as for the M condition, but that, given the same number of repetitions per list, the association strengths established for the L condition all tend to be weaker than those for the M condition. This may be represented by drawing the curve for the p lists displaced to the left of that for the P lists, or, in short, by curve b′c′d′e′. The threshold is the same as before, and hence area f′c′e′ now represents *r* for the p lists, and assuming an exactly equal inhibition produced by the work in both cases, area g′d′e′ will represent *r* for the w lists. It is evident that the drop in *r* will appear less than it did in the case of the M condition, i.e., area f′c′d′g′ is less than area fcdg. It is therefore plain that in order for the differences between *r* for the passive lists and for the work lists to give a sure indication of the true differences in degree of inhibition for the two cases, the same portions of the distribution curve must be affected.

It follows that, if we are to prove conclusively that the L condition is really more affected by retroactive inhibition than the M condition, we must regulate our results (by extra repetitions, if necessary, in the case of the L condition), so that *r* for the p lists is equal to or greater than that for the P lists. Only then will a greater difference of (*r* for p lists)—(*r* for w lists) than (*r* for P lists)—(*r* for W lists) indicate conclusively that the L condition was more affected by work.

As a result of such reasoning, in each of our experiments more repetitions were given on the average in the L condition than in the M condition. Furthermore, the numbers of repetitions were varied from time to time during the course of a single experiment, if variations in the freshness or practice of a subject seemed to make it necessary, to insure an equal or greater *r* for the p lists than for the P lists. In changing the number of repetitions, however, those for the w lists were of course always kept equal to those for the p lists, and those for the W lists to those for the P lists.[11]

Other peculiarities of method were as follows.

A day or more of practice always preceded each actual experiment.

Successive experiment-days did not always coincide with successive calendar days, but did so as nearly as possible. The experiment-hours were kept the same throughout any one experiment.

The positions of the p, w, P. W lists within the experiment-hour were interchanged from day to day. This occurred either according to a regular sequence (Systematic variation of "time-position"), or in an irregular manner (Irregular variation of "time-position"). In either case a 'Cycle" of variations involved a complete interchanging of lists such that each kind of list had occupied each position within the hour (i.e., each time-position) an equal number of times.

The intervals between testing one list and learning the next were always short, averaging less than a minute. They were merely long enough to prepare the apparatus for the next list. Such short waits were necessary in order not to put too great a demand upon the subject's time.[12]

As "work," the checker-board arrangements of either 25 two-place numbers or 25 differently colored consonants were studied by the subject for a prescribed interval (either 2½ or 3 minutes), and then recalled orally.

The "passive" intervals were usually spent by the women subjects[13] in sewing or knitting. They were spent by the men in resting in an easy chair, in walking about the room, or glancing through a pile of magazines.[14]

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[11] A similar procedure was adopted by Heine in experiments upon the relative inhibition of weak and strong associations. Op. cit., p. 217, and see also above p. 6.

[12] It is probable that this increased the unevenness in learning-value of the different time-positions.

[13] There was one exception. In the case of Exp. 5, subject T. spent her time in glancing through the newspaper or a pile of magazines.

Introspection during the course of the experiments was not asked for, but was noted when given. This procedure was adopted in accordance with Müller's prescription for reliable objective results.[15]

In presenting the results, we have given only (1) the mean percentum of correct responses and (2) the median percentum of correct responses. We have not presented mean variations, because they might tend to give a false idea of lack of precision in our results. The effect of such factors as practice and time-positions is to make the mean variations large. But since these factors are made as nearly as possible the same for each kind of lists, the size of the mean variations is not a fair test of the precision of the final comparison.[16] A more reliable way of determining precision would seem to lie in the examination of the results for the individual "cycles." These we have presented.

Our subjects were as follows: Mr. E. Norris (N), graduate student in psychology; Mr. L. Vernon (V), undergraduate student in psychology; Mrs. A. P. Carter (C), no psychological training; Miss E. C. Carter (Ca), no psychological training; Mrs. E. C. Tolman (T), no psychological training; and the author (To).

In every experiment, save that in which the writer was the subject, there was complete ignorance on the part of the subject of the purpose of the experiment. Furthermore, in the experiment in which the writer was subject, the arrangement was such that his knowledge of the purpose could not conceivably affect his results one way or the other.

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[14] In some preliminary experiments and in Exp. 6, the subject listened to dropping water while lying in an easy chair with eyes closed. It was thought that such complete abstraction in the "passive" intervals might make the inhibitory effect produced by the "work" intervals appear bigger. No such influence was discovered.

[15] Müller, G. E. Zeitschrift für Psychologie, Ergänzungsband 5, 1911, p. 130.

[16] See Müller, G. E. a,nd Schumann, F., op. cit., pp. 266-279.

CHAPTER IV

PRESENTATION OF RESULTS

I. Pleasant vs. Indifferent Lists. Exps. 1, 2, 3, and 4.

In connection with each of these experiments an attempt was made to show independently by means of simple learning tests the relatively greater stimulating value of the pleasant lists as opposed to the indifferent lists.[1] In Experiments 1 and 2, this determination was made by means of subsidiary experiments performed prior to the main experiment. In Experiments 3 and 4 it was done as part of the main experiment.

In all the experiments the subjects were told before the presentation of each list whether it was to be pleasant or indifferent. It was hoped that this would increase the subjective difference between the two kinds of lists.

Experiment 1. Subject C.

Subsidiary Experiment. All-word lists (10 words each), method of Complete Learning (Erlernungsmethode), R. L. Gedächtnisapparat. Time of one revolution 10.8 sec. Six lists learned in an experiment hour: two pleasant lists, two indifferent lists, and two unpleasant lists.[2] Systematic variation of the time-position of lists. Cycle complete in three exp. hours.

Results. (6 exp. days, n=12.)

	R	
Pleasant	11.5	(12.0)
Indifferent	12.7	(12.5)
Unpleasant	13.5	(13.0)

Under the caption R are given the average numbers of repetitions for a successful recitation (inclusive of the recitation). The figures in brackets give the median values.[3] n is the number of each kind of list learned.

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[1] See above footnote, p. 17.

[2] The inclusion of the unpleasant lists was the result of an original purpose of investigating thoroughly the effects of unpleasant as well as pleasant feeling-tones, a purpose which was afterwards abandoned.

[3] These medians and all the others which we shall present in this paper were obtained simply by arranging the figures in order of magnitude and taking the middle one in the case of an odd number of figures or taking an average of the two middle ones in the case of an even number of figures.

The results seem to indicate that pleasant words were for this subject more stimulating, in the sense at least of being more readily learned, than were indifferent words.

Main Experiment. R. L. apparatus. Time of one revolution 10.8 sec. Reproduction times not measured. Ten-place lists of alternate three-place numbers and words. Systematic variation of the time-position of the lists. Cycle of variation complete in four experiment hours. Repetitions: pleasant lists 3-2, average 2.5; indifferent lists 4-2, average 3.1. Time-interval[4] 9 minutes. Work: 3 min. studying checker-board of numbers or consonants (on alternate days).

		Pleasant			Indifferent	
		r			*r*	
Complete results.	P	60.0	(60.0)	p	80.0	(80.0)
(8 exp.-days)	W	40.0	(40.0)	w	35.0	(30.0)
n=40						
		Nos.	*Cons.*		*Nos.*	*Cons.*
Work:		15.0	10.5		15.8	10.0
		r			*r*	
First cycle.	P	70.0	(70.0)	p	75.0	(80.0)
(4 exp.-days)	W	45.0	(50.0)	w	40.0	(40.0)
n=20						
		r			*r*	
Second cycle	P	50.0	(50.0)	p	85.0	(90.0)
(4 exp.-days)	W	35.0	(30.0)	w	30.0	(30.0)
n=20						

n here stands for number of number-word pairs in each group of lists.[5] *r* stands for percentages of correct responses. The figures outside the brackets are averages. Those within are medians.[6] P, W, p, and w stand for pleasant lists passive condition, pleasant lists work condition, indifferent lists passive condition, and indifferent lists work condition, respectively. Opposite "Work" are given the average number of numbers (Nos) and colored consonants (Cons) learned after the three minutes study in the case of the work conditions.

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[4] By "time-interval" we shall mean the time between the end of the learning and the beginning of the Right Associates test.

[5] Wherever the Savings method is used n will stand for the number of *lists* in each group; wherever the Right Associates method is used, for the number of number-word pairs (or nonsense syllable pairs) in each group.

[6] We computed the median number of correct syllables recalled per list for the condition in question, and divided the figures so obtained by the total number of recalls per list possible (in this experiment, 5).

It will be observed at once that both the complete results and the results for the individual cycles indicate a greater inhibition for the indifferent lists than for the pleasant lists. Not only is the drop in *r* for the indifferent lists in each case greater than that for the pleasant lists, but the values for the indifferent lists are inclusive of those for the pleasant lists.[7]

Turning to the work, i.e., the number of numbers or consonants learned in the three minute period, we note but little difference in the two cases.

We conclude that this experiment points to a real difference between the effects of retroactive inhibition after pleasant learning and after indifferent learning.

Experiment 2. Subject T.

The main experiment was preceded by two subsidiary experiments to determine the relative stimulating values of the two kinds of lists.

Subsidiary Experiment A. All-word lists. Four lists: two pleasant, two indifferent, learned and relearned in each experiment-hour. Systematic variation of the time-positions. Kymograph drum and gravity motor. Time of one rev. 13-14 sec. We present the results for original learnings only.

Results. (3 exp. days, n=6)

	R	
Pleasant	13.8	(14.0)
Indifferent	16.2	(17.0)

Subsidiary Experiment B. This experiment followed subsidiary experiment A, but instead of all-word lists, number-word lists were used (numbers were two-place), and the lists were merely learned, not relearned. Eight lists, four pleasant and four indifferent, were learned in each exp.-hour. Systematic variation of time-position of lists. Kymograph drum and gravity motor. Time of one rev. 10.5 sec.

Results. (2 exp. days, n=8)

	R	
Pleasant	14.3	(15.0)
Indifferent	14.9	(13.5)

Subsidiary Experiment A indicates that the pleasant lists were more stimulating for this subject than the indifferent lists. Subsidiary Experiment B, on the other hand, is non-committal. The results for the medians contradict those for the means.

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[7] See above pp. 18-19.

We may turn to the results of the main experiment which followed Subsidiary Experiment B.

Main Experiment. Kymograph drum and gravity motor. Time of one rev. 10.5 sec. Response times not measured. Twelve-place lists of alternate two-place numbers and words. Systematic variation of the time-position of the lists. Cycle of variation complete in four exp.-hours. Repetitions: pleasant lists 10-8, average 8.9; indifferent lists, 10-9, average 9.8. Time-interval 9 mins. Work: 3 mins. of studying checkerboard of numbers or consonants (on alternate days).

		Pleasant			Indifferent	
		r			*r*	
Complete results.	P	52.1	(50.0)	p	60.0	(65.0)
(8 exp.-days)	W	64.6	(66.7)	w	47.9	(50.0)
n=48						
		Nos.	*Cons.*		*Nos.*	*Cons.*
Work:		14.0	10.3		10.6	9.7
		r			*r*	
First cycle	P	62.5	(66.7)	p	74.2	(81.7)
(4 exp.-days)	W	58.3	(58.3)	w	38.5	(33.3)
n=24						
		r			*r*	
Second cycle	P	41.7	(50.0)	p	45.8	(41.7)
(4 exp.-days)	W	70.8	(66.7)	w	58.3	(50.0)
n=24						

The captions have the same meanings here as in the previous experiment.

We may note first as regards the "work" that the number of numbers or consonants learned tended to be greater after the pleasant lists than after the indifferent. Greater inhibition for the indifferent lists was not, therefore, due to harder work after these lists.

Considering the final results for the complete experiment, we note that whereas the figures for the indifferent lists indicate inhibition, those for the pleasant lists indicate facilitation. The question arises whether both effects may not have been the result of chance. Facilitation, it would seem, could only have been due to chance, and if so, why should not the opposite and practically no larger inhibition also have been the result of chance? This is indeed a possibility.

Let us turn, however, to the results for the individual cycles.

It may be remarked, in passing, that in the case of this particular experiment the last experiment day of the first cycle and the first experiment day of the second cycle were separated by an interval of 17 days,[8] so that in a sense the two cycles were more like two independent experiments than like two parts of the same experiment.

In the case of Cycle 1, we find evidence of inhibition for both sets of lists. Furthermore, they support the results of Experiment 1, since the inhibition for the indifferent lists is strikingly greater than for the pleasant lists. In Cycle 2, on the other hand, we find facilitation for both sets of lists. But it must be noted that this facilitation is less for the indifferent than for the pleasant lists. The possibility is therefore suggested that in this cycle, also, there was a real tendency towards inhibition for the indifferent lists as compared with the pleasant lists, but that chance or some other indefinable factor entered in and blurred the results. At any rate, it would seem safe to conclude that, although the total results of Experiment 2, in themselves, may seem to point to no conclusion, the results for the two cycles taken separately and compared with those of Experiment 1 do seem to afford further evidence for the conclusion that indifferent lists have more of a tendency to be inhibited by succeeding work than have pleasant lists.

Let us turn now to Experiments 3 and 4. In these two experiments, the relative stimulating values of the two kinds of lists were measured by means of immediate recall tests carried on as part of the main experiments. In these recall tests, lists of 12 words each, one pleasant list and one indifferent, were presented by means of the kymograph drum. After one revolution of the drum, the subject was asked to recall (in any order) as many of the words as he could.

Experiment 3. Subject V.

Kymograph drum. Electric motor. Time of one rev. 12.0 sec. Response times not measured. Ten-place lists of alternate three-place numbers and words. Systematic variation of the time-position of lists. Cycle of variation complete in four experiment-hours. Repetitions: pleasant lists 11-8, average 8.9; indifferent lists 12-10, average 10.9. Time-interval 6 minutes. Work: 3 min. studying checkerboard of consonants.

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[8] This was the only experiment in which an interval of more than two or three calendar days intervened between successive experiment days.

		Pleasant				Indifferent		
		r		Wds.		*r*		Wds.
Complete results.	P	52.5	(50.0)		p	52.5	(40.0)	
(8 exp.-days)				6.4				5.8
n=40	W	57.5	(60.0)		w	42.5	(40.0)	
		Cons.				*Cons.*		
Work:		6.4				7.1		
		r				*r*		
First cycle	P	45.0	(50.0)		p	30.0	(30.0)	
(4 exp.-days)	W	45.0	(60.0)		w	35.0	(40.0)	
n=20								
		r				*r*		
Second cycle	P	60.0	(60.0)		p	75.0	(80.0)	
(4 exp.-days)	W	70.0	(80.0)		w	50.0	(50.0)	
n=20								

Under the caption Wds are given the average numbers of pleasant and indifferent words recalled in the immediate recall tests. We see a slight tendency to recall more pleasant than indifferent words. As regards the work, it is to be noted that a slightly greater number of consonants was learned after the indifferent lists than after the pleasant. The difference, however, is small, and probably not enough to have made in itself any difference in the inhibition produced in the two cases.

Examining the main results, we see that the indications in any direction are but slight. The complete figures here, as in the case of the previous experiment, indicate facilitation for the pleasant lists and inhibition for the indifferent. The figures for the individual cycles do not make these final results much clearer. Those for Cycle 1 suggest slight facilitation for both pleasant and indifferent lists, with no appreciable advantage for either. Those for Cycle 2 indicate facilitation for the pleasant lists and inhibition effect for the indifferent lists. We conclude that the results of this experiment taken by themselves would prove but little. When combined, however, with those of the two preceding experiments they add their slight quota of further testimony to the conclusion that indifferent lists are relatively more affected by inhibition than are pleasant lists.

Let us turn to Experiment 4.

Experiment 4. Subject N.

Conditions exactly the same as in the previous experiment save for the numbers of repetitions. Repetitions: pleasant lists 9-6, average 7.6; indifferent lists 10-8, average 8.6.

		Pleasant				Indifferent		
		r		Wds.		*r*		Wds.
Complete results.	P	42.5	(30.0)		p	46.3	(50.0)	
(8 exp.-days)				7.4				6.7
n=40	W	55.0	(50.0)		w	47.5	(40.0)	
		Cons.				*Cons.*		
Work:		14.1				14.1		
		r				*r*		
First cycle	P	20.0	(20.0)		p	57.5	(60.0)	
(4 exp.-days)	W	45.0	(30.0)		w	65.0	(60.0)	
n=20								
		r				*r*		
Second cycle	P	65.0	(60.0)		p	35.0	(30.0)	
(4 exp.-days)	W	65.0	(60.0)		w	30.0	(30.0)	
n=20								

These figures need but little separate discussion. They are similar to those for the preceding experiment. Combined with them they add their evidence to the conclusion that indifferent lists tend to be more affected by inhibition than pleasant ones.

Let us sum up as regards these pleasant vs. indifferent experiments. We note that the last three, in so far as they indicate no inhibition or even facilitation for the pleasant lists, and but slight inhibition for the indifferent lists, support the negative findings of De Camp. However, in so far as when combined with Experiment 1 they present a uniform tendency for retroactive inhibition to appear more *readily* in the indifferent lists, they point to a new and striking possibility; the possibility, namely, that in the case of two contrasted conditions of learning, one condition may be consistently more affected by retroactive inhibition than the other.

It was precisely to test out this possibility further that the succeeding experiments were undertaken. A difficulty encountered with the present experiments was that the difference in feeling-tone was for most subjects in all probability but slight. This fact appeared particularly in the last three experiments, not only from the special tests to measure relative stimulating values, but also from incidental introspection. Because of this condition, which may well have been the cause in part for the somewhat indecisive character of the results, we decided to substitute for pleasantness and indifference some other pair of conditions which might present a more constant but similar contrast. In the pursuance of this problem we attempted, first, a comparison of the results of learning under normal attention with those of learning under divided attention. The results of the experiment are given in the next section.

II. Normal vs. Distracted Attention. Exp. 5.

The distracted attention was brought about as follows. A telegraph key was connected with contacts upon the drum in such a way that it tapped a group of one, two, or three taps simultaneously with the presentation of every pair of list elements. The subject at the same time that she was reading the lists was required to duplicate the taps by striking a pencil on the table. The distraction thus obtained was very considerable and yet not so great but that the subject was quite able to read the list correctly and to make progress towards learning it. The grouping of the taps was different for successive repetitions, so that the degree of distraction remained practically constant throughout the entire presentation of a list. The other conditions and results were as follows.

Experiment 5. Subject T.

Kymograph drum. Electric motor. Time of one rev. 12.0 sec. Response times not measured. Twelve-place lists of alternate nonsense syllables and one-syllable words. Systematic variation of the time-position of lists. Cycle of variations complete in four experiment-hours. Repetitions: normal lists 7-6, average 6.4; lists with distracted attention 18-14, average 16.8. Time-interval 6 minutes. Work: 2 min. studying checkerboard of consonants or numbers (on alternate days).

Examining the complete results, we observe no appreciable tendency for either condition to show more retroactive inhibition

		Normal Attention			Distracted Attention	
		r			*r*	
Complete results.	P	43.1	(33.3)	p	41.7	(33.3)
(12 exp.-days)	W	37.5	(33.3)	w	37.5	(33.3)
n=72						
		Nos.	*Cons.*		*Nos.*	*Cons.*
Work:		14.2	10.9		14.4	10.2
		r			*r*	
First cycle	P	29.2	(25.0)	p	54.2	(50.0)
(4 exp.-days)	W	29.2	(25.0)	w	29.2	(33.3)
n=24						
		r			*r*	
Second cycle	P	50.0	(50.0)	p	29.2	(25.0)
(4 exp.-days)	W	45.8	(33.3)	w	41.7	(41.7)
n=24						
		r			*r*	
Third cycle	P	50.0	(50.0)	p	41.7	(41.7)
(4 exp.-days)	W	37.5	(41.7)	w	41.7	(50.0)
n=24						

than the other. The individual cycles confirm this finding. The results for the successive cycles do not agree with one another, and hence the negative outcome of the complete results was to be expected. We may note, finally, that these negative results not only show no greater evidence of inhibition for one condition than for the other, but also very little inhibition for either condition. In short, De Camp's completely negative findings tend to be supported.

We conclude that this comparison of normal and distracted attention did not present the contrast between a condition more susceptible to inhibition and one less susceptible to inhibition which we were looking for.

In the next section we present experiments contrasting the effects upon retroactive inhibition of learning with caffeine and of learning without caffeine.

III. With Caffeine vs. without Caffeine. Exps. 6 and 7.

The general conditions of the experiment were as follows.

1½ grain capsules of caffeine were taken by the subjects on alternate days. Sugar of milk capsules of similar appearance were given on the in-between days. The subjects were thus unaware which were the caffeine days and which the non-caffeine days. The capsules were given sometimes before, sometimes at, and sometimes just after the morning meal. The experiments were performed on an average of 2½ to 3 hours later. Schedules of the exact hours are presented below. The subjects refrained from all use of tea, coffee, or chocolate throughout the course of the experiment.[9]

Experiment 6. Subject To.

In this experiment the writer himself acted as subject. He remained totally ignorant of the way in which the results were coming out until after the conclusion of the experiment.[10] Previous to the time of the experiment he had been an occasional user only of coffee, tea, or chocolate.

The schedule of hours at which capsules were administered and experiments performed is given below.

Date	*Capsule.*	*Hour for Capsule.*	*Hour of Exp.*	
May 31	Caffeine	8.30	11.00	Practice
June 1	S of M	8.30	11.00	Main Exp.
“ 2	Caffeine	7.10	11.00	“ “
“ 3	S of M	7.45	11.00	“ “
“ 4	Caffeine	9.00 Sunday	No Exp.	
“ 5	S of M	8.15	11.20	“ “
“ 6	Caffeine	8.15	11.00	“ “
“ 7	S of M	8.15	11.00	“ “
“ 8	Caffeine	8.30	11.00	“ “
“ 9	S of M	8.30	No Exp.	
“ 10	Caffeine	8.30	“ “	
“ 11	S of M	8.30	“ “	
“ 12	Caffeine	8.45	11.00	“ “

In each experiment hour four lists were learned, two with work and two without. Kymograph drum, electric motor. Time of one rev. 9.0 secs. Response times measured. Lip-key style A. Twelve-place nonsense syllable lists. Systematic variation of the time-position of the lists. Cycle of variation complete in eight experiment-hours. Repetitions: with caffeine 10-9, average 9.5; without caffeine 11-10, average 10.5. Time-interval 7½ minutes. Work: 2 min. studying checkerboard of consonants.

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[9] The general method of procedure as regards caffeine was an adaptation from that presented by Hollingworth, H. L., Archives of Psychology, Vol. XX, No. 4.

[10] The writer's acknowledgements are due to Miss Esther Watt, A.M. in psychology, who served as experimenter.

		With Caffeine.			Without Caffeine.	
		r			*r*	
Complete results.	P	37.5	(33.3)	p	50.0	(50.0)
(8 exp.-days)	W	41.7	(41.7)	w	27.1	(25.0)
n=48.						
		TA	T<2 sec.		TA	T<2 sec.
	P	4.5	9	p	6.3	7
	W	6.0	9	w	6.1	2
		Cons.			*Cons.*	
Work:		20.6			19.4	

Under the caption TA are given the average times for the correct responses; under T<2 sec., the absolute number of correct responses with time equal to or less than 2.0 sec.[11] The other symbols have the same meaning as in previous tables.

The values for the percentages of correct responses show no inhibition for the caffeine days, but decided inhibition for the non-caffeine days, and this, although the work accomplished in terms of the number of consonants learned seems to have been greater for the caffeine than for the non-caffeine days. This bears out our supposition that caffeine and non-caffeine might give results similar to those obtained from pleasant and indifferent lists.

We shall not now discuss the time-values. Taken separately they indicate no very clear conclusion. We shall therefore reserve our discussion of them until we have obtained those for all the other experiments in which times were measured.

Let us turn now to the second experiment upon the effects of caffeine.

Experiment 7. Subject T.

The general conditions were similar to those for the preceding experiment.

The schedule for caffeine and sugar of milk capsules is shown below.

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[11] In thus presenting the numbers of relatively short times in addition to the mean times we have followed the precedent of Müller and Pilzecker. See op. cit., pp. 41-43.

Date	Capsule.	Hour for Capsule.	Hour of Exp.	
July 1	Caffeine	9.00	12.00	Practice.
" 2	S of M	9.00	12.00	Main Exp.
" 3	Caffeine	8.10	11.20	" "
" 4	S of M	8.25	11.30	" "
" 5	Caffeine	8.10	11.30	" "
" 6	S of M	8.20	11.20	" "
" 7	Caffeine	8.30	11.30	" "
" 8	S of M	8.30	11.30	" "
" 9	Caffeine	9.30	12.30	" "
" 10	S of M	8.30	11.30	" "
" 11	Caffeine	8.30	11.30	" "
" 12	S of M	8.00	11.00	" "
" 13	Caffeine	7.30	10.45	" "

In each experiment-hour 4 lists were learned, two with work and two without. R. L. Gedächtnisapparat. Time of one rev. 10.8 sec. Response times measured. Lip-key, style B. Twelve-place nonsense syllable lists. Systematic variation of the time-position of the lists. Cycle of variation for both with caffeine and without caffeine, complete in four exp.-hours. Repetitions: with caffeine 15, average 15.0; without caffeine 15-13, average 13.8. Time-interval 7½ minutes. Work: 2 min. studying checkerboard of consonants.

	With Caffeine.			Without Caffeine.		
		r			*r*	
Complete results.	P	41.7	(33.3)	p	55.6	(58.3)
(12 exp.-days)	W	29.2	(33.3)	w	30.6	(33.3)
n=72.						
		T_A	$T<1.4$sec.		T_A	$T<1.4$sec.
	P	1.8	20	p	2.3	16
	W	1.9	7	w	2.7	5
Work:		*Cons.*			*Cons.*	
		21.0			19.4	
		r			*r*	
First Cycle	P	58.3	(58.3)	p	50.0	(58.3)
(4 exp.-days)	W	20.8	(16.7)	w	29.2	(33.3)
n=24						
		r			*r*	
Second Cycle	P	33.3	(33.3)	p	50.0	(50.0)
(4 exp.-days)	W	45.9	(50.0)	w	29.2	(33.3)
n=24						
		r			*r*	
Third Cycle	P	33.3	(25.0)	p	66.7	(66.7)
(4 exp.-days)	W	20.8	(25.0)	w	33.3	(33.3)
n=24						

Examining the percentages of correct responses for the complete results, we again find greater inhibition for the days without caffeine than for those with caffeine,[12] and this result is carried out by the figures for the last two cycles. It is to be noted that the number of consonants learned was greater for the caffeine than for the non-caffeine days. The time-values will be discussed later.

We conclude that these results substantiate those for the preceding experiment. Because, however, of the difficulties connected with the strict regimen required of the subjects, no further experiments using caffeine were undertaken.

As a final method of presenting more and less stimulating conditions, we tried the effects of relatively efficient and inefficient working periods of the day. To those experiments we now turn.

IV. Efficient vs. Inefficient Working Periods. Exps. 8, 9, 10, 11, 12, and 13.

In these experiments the results for lists learned in a morning period were compared with those for lists learned directly after the mid-day meal, or, in the case of two experiments, with those for lists learned in the evening. In each learning period two lists were learned: one a "passive" and one a "work" list. Whether the "passive" or the "work" list was to come first could not be guessed beforehand by the subject, as the two orders, 'work' 'passive,' and 'passive' 'work,' were mixed haphazard throughout a cycle (Irregular variation of time-positions). A cycle consisted of six (or in some cases four) experiment days in which the two orders, 'work' 'passive' and 'passive' 'work', occurred in equal numbers both in the efficient and in the inefficient periods. Other conditions were similar to those in the preceding experiments.

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[12] The average value for the w lists for the non-caffeine days is, to be sure, not quite as small as that for the caffeine days. The difference is so slight, however, that it hardly seems a significant deviation from our prescribed rule, especially since the median values fulfill the requirement. A few less repetitions on the days without caffeine would easily have reduced r for w to that for W, without making r for p as small as that for P.

Experiment 8. Subject C. Morning and Evening.

R. L. Gedächtnisapparat. Time of one rev. 10.8 sec. Response times measured. Lip-kep style B. Ten-place nonsense syllable lists. Irregular variation of the time-position of the lists. Two cycles of variation: first complete in 6 days; second complete in 4 days. Repetitions: morning 13-8 average 9.5; evening 26-20, average 21.8. Time-interval 8½ minutes. Work: 2 min. studying checkerboard of numbers.

		Morning.			Evening.	
		r			*r*	
Complete results.	P	44.0	(40.0)	p	52.0	(60.0)
(10 exp.-days)	W	42.0	(50.0)	w	34.0	(20.0)
n=50						
		TA	T<2.0sec.		TA	T<2.0sec.
	P	3.5	9	p	4.3	4
	W	4.7	7	w	5.7	4
		Nos.			*Nos.*	
Work:		12.4			12.4	
		r			*r*	
First Cycle	P	53.3	(60.0)	p	53.3	(50.0)
(6 exp.-days)	W	46.7	(60.0)	w	26.7	(20.0)
n=30						
		r			*r*	
Second Cycle	P	30.0	(30.0)	p	50.0	(60.0)
(4 exp.-days)	W	35.0	(30.0)	w	45.0	(50.0)
n=20						

The values for the percentages indicate quite decidedly bigger inhibition for the evening than for the morning. We find this to be true not only for the final results but also for the individual cycles. The average number of numbers remembered was the same for both conditions. The time values will be considered later.

The next experiment was performed with the same subject. An interval of three weeks elapsed between the two experiments. The results are similar to the above though not perhaps as decisive.

Experiment 9. Subject C. Morning and Evening.

One cycle only, complete in 6 days. Repetitions: morning 12-8, average 9.3; evening 15-10, average 12.5. Other conditions same as in Exp. 8.

		Morning.			Evening.	
		r			*r*	
Complete results.	P	36.7 (40.0)		p	43.3 (40.0)	
(6 exp.-days)	W	26.7 (30.0)		w	26.7 (30.0)	
n=30						
		T_A	$T<1.8$sec.		T_A	$T<1.8$sec.
	P	2.8	3	p	3.2	3
	W	5.7	3	w	3.9	1
		Nos.			*Nos.*	
Work:		14.5			13.7	

The percentages of correct responses indicate only a slightly greater inhibition for the evening than for the morning. More numbers were learned for work in the morning than in the evening. Time values will be discussed later.

In comparing these results with those of the two cycles of the preceding experiment, it will be observed that the first cycle of the preceding experiment gave the most pronounced results, the second cycle of that experiment came next, while the one cycle of this experiment comes last. Now it is to be noted that these experiments were performed during the summer vacation, and that at the beginning of the first one the subject was tired as a result of a strenuous winter, but as they went on she became more and more rested. (She testified to this herself without at all knowing the purpose of the experiment.) If, now, we may assume that her general tired condition at the beginning of the first experiment tended to affect the evening hour relatively more than the morning hour, but that as she became gradually more rested the difference in efficiency between the two periods tended to disappear, we have an explanation for the decrease in the clearness of the results as the experiments progressed. That such an assumption is justifiable the writer firmly believes. It accords with his personal observation of the subject at the time, and also with the objective fact that as the experiments progressed the excess number of repetitions which had to be given in the evening was much cut down. In the first of the two experiments (see above), the evening repetitions varied from 26 to 20, average 21.8; the morning repetitions varied from 13 to 8, average 9.7. In the second experiment, the morning repetitions varied from 12 to 8, average 9.3; the evening repetitions, on the other hand, were reduced to a variation of only 15 to 10, average 12.5. These figures seem to indicate that in the earlier experiment the evening hour was relatively much more inefficient as compared with the morning hour than in the later experiment. Hence the more pronounced results of the first experiment.

We turn now to the next experiment, using a different subject.

Experiment 10. Subject T. Morning vs. Afternoon (directly after the mid-day meal).

One cycle only, complete in 6 days. Repetitions: morning 12-8, average 9.7; afternoon 18-12, average 14.8. Other conditions same as in Experiments 8 and 9.

		Morning.			Afternoon.	
		r			*r*	
Complete results.	P	50.0	(50.0)	p	50.0	(50.0)
(6 exp.-days)	W	36.7	(40.0)	w	23.3	(20.0)
n=30						
		TA	T<1.2sec.		TA	T<1.2sec.
	P	1.8	5	p	1.9	3
	W	2.2	2	w	2.0	2
		Nos.			*Nos.*	
Work:		11.1			11.3	

Both the average and median percentages of correct responses show greater inhibition for the afternoon than for the morning. A slightly bigger average for the numbers learned in work was obtained for the afternoon. The time values will be considered later.

The same subject was used in the next experiment. An interval of five weeks elapsed between the two experiments.

Experiment 11. Subject T. Morning vs. Afternoon (directly after the mid-day meal).

One cycle only, complete in 6 days. Repetitions: morning 9, average 9.0; afternoon 14, average 14.0. Other conditions same as in Exps. 8, 9, and 10.

		Morning.			Afternoon.	
		r			*r*	
Complete results.	P	56.7 (60.0)		p	56.7 (50.0)	
(6 exp.-days)	W	43.3 (50.0)		w	26.7 (30.0)	
n=30						
		T_A	$T<1.6$sec.		T_A	$T<1.6$sec.
	P	1.9	7	p	2.0	6
	W	2.8	4	w	2.0	4
		Nos.			*Nos.*	
Work:		13.3			12.3	

Again we find greater inhibition for the afternoon than for the morning. More numbers were learned in the morning than in the afternoon hour. The time values will be discussed later.

The final experiments were performed on a third subject.

Experiment 12. Subject Ca. Morning vs. Afternoon (directly after the mid-day meal).

One cycle only, complete in 6 days. Repetitions: morning 8-6, average 7.2; afternoon 10-7, average 9.0. Other conditions same as in Exps. 8, 9, 10, and 11.

		Morning.			Afternoon.	
		r			*r*	
Complete results.	P	66.7 (70.0)		p	66.7 (80.0)	
(6 exp.-days)	W	60.0 (60.0)		w	50.0 (40.0)	
n=30						
		T_A	$T<2.2$sec.		T_A	$T<2.2$sec.
	P	4.8	10	p	6.0	5
	W	4.3	7	w	4.5	5
		Nos.			*Nos.*	
Work:		17.0			14.3	

Again greater inhibition is found for the afternoon. This time the average for the numbers learned was much greater for the morning work than for the afternoon work. Time values will be discussed later.

The next experiment, which used the same subject, succeeded this one after an interval of 9 days.

Experiment 13. Subject Ca. Morning vs. Afternoon (directly after the mid-day meal).

Two cycles. First cycle complete in 6 days; second cycle complete in 4 days. Repetitions: morning 6-4, average 4.5; afternoon 10-7, average 8.4. Other conditions same as in Exps. 8, 9, 10, 11, and 12.

		Morning.			Afternoon.	
		r			*r*	
Complete results.	P	54.0	(40.0)	p	68.0	(70.0)
(10 exp.-days)	W	56.0	(60.0)	w	48.0	(40.0)
n=50						
		T_A	$T<1.4$sec.		T_A	$T<1.4$sec.
	P	2.9	13	p	4.7	6
	W	3.4	9	w	5.2	8
		Nos.			*Nos.*	
Work:		19.4			16.7	
		r			*r*	
First Cycle	P	60.0	(50.0)	p	66.7	(70.0)
(6 exp.-days)	W	53.0	(60.0)	w	46.7	(40.0)
n=30						
		r			*r*	
Second Cycle	P	45.0	(40.0)	p	70.0	(70.0)
(4 exp.-days)	W	60.0	(70.0)	w	50.0	(50.0)
n=20						

Again all the figures for percentages of correct responses, those for the individual cycles as well as the complete results, show greater inhibition for the afternoon than for the morning. Time values will be discussed in the next section.

Reviewing the results for these six experiments, we find that *without exception the lists learned in the inefficient hour of the day showed more inhibition, in terms of percentages of correct responses, than did those learned in the efficient hour of the day.*

V. Numbers of Repetitions; Work.

It has already been remarked[13] that our choice of the terms More and Less Stimulating to cover the contrasts pleasant and indifferent, with caffeine and without caffeine, efficient period and inefficient period, was due to certain characteristics common to these contrasts, aside from that of their behavior as to retroactive inhibition. These other characteristics concern: (1) the relative numbers of repetitions required to produce the same amount of learning, (2) the relative amounts of work accom-

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[16] Above: footnote, p. 3.

plished in equal work periods, and (3) the relative times for the correct responses.

Let us consider these factors in order. The first two will be summarized in the present section, the last of the three in the following one.

The relative numbers of repetitions required to produce the same amount of learning (or the complementary fact of the relative amounts of learning produced by the same number of repetitions) we will designate *learnability.* Turning to this learnability as expressed in the relative numbers of repetitions for the contrasted kinds of lists, we are led to the following analysis.

It will be recalled that in order to insure a percentage of correct responses for the p lists as big as or bigger than that for the P lists we gave as a rule more repetitions to the former than to the latter. Now, in those cases where it appears that this excess of repetitions raised the percentage of correct responses of the former to only about equal to that for the latter, we will have evidence that the latter possessed greater learnability than the former. In the cases, however, where it appears that the excess of repetitions raised the percentage of correct responses of the p lists to more than that for the P lists, the evidence of greater learnability for the latter will not be so clear unless, indeed, the excess in repetitions for the p lists is obviously incommensurably great as compared with the excess in percentage of correct responses produced.

The following table summarizes the results for all 13 experiments.

R stands for average number of repetitions and *r* for average percentage of correct responses. P and p stand for More Stimulated and Less Stimulated Passive lists, respectively.

The figures for Experiment 5 (normal vs. distracted attention) may be eliminated at once from present consideration; for, although they indicate enormously more repetitions for the p lists than for the P lists, together with only about equal percentages of correct responses, the fact that this experiment failed to show the characteristic difference as to retroactive inhibition excludes it from our present interest.

	Exp.	R		r	
		P	p	P	p
Pleasant vs. Indifferent	1	2.5	3.1	60.0	80.0
	2	8.9	9.8	52.1	60.0
	3	8.9	10.9	52.5	52.5
	4	7.6	8.6	42.5	46.3
Normal vs. Distracted	5	6.4	16.8	43.1	41.7
Caffeine vs. without Caffeine	6	9.5	10.5	37.5	50.0
	7	13.8	15.0	41.7	55.6
Efficient vs. Inefficient	8	9.5	21.8	44.0	52.0
	9	9.3	12.5	36.7	43.3
	10	9.7	14.8	50.0	50.0
	11	9.0	14.0	56.7	56.7
	12	7.2	9.0	66.7	66.7
	13	4.5	8.4	54.0	68.0

Turning to the other twelve experiments for each of which some evidence of greater inhibition for the Less Stimulating condition was found, we note among the four pleasant vs. indifferent experiments one (Exp. 3) for which the percentage of correct responses for p is no greater than that for P, although the average number of repetitions for the former is greater, and one other experiment (Exp. 4) for which the percentage of correct responses for p is only slightly greater, although the number of repetitions is decidedly greater. For these two experiments, therefore, the figures show evidence of greater learnability (i.e., Greater Stimulating value) for the P lists. For the other two pleasant vs. indifferent experiments, on the other hand, the figures point to no certain conclusion.

It is evident, however, that in the case of the pleasant vs. indifferent experiments we have other independent evidence of relative learnability: namely, the evidence presented by our subsidiary experiments. Referring back to these we find that for Experiment 1 the subsidiary experiment seemed to show decided evidence of greater learnability for the pleasant (P) lists. For Experiment 2, on the other hand, the two subsidiary experiments contradicted one another. For Experiments 3 and 4 the subsidiary experiments agreed with the present figures in indicating greater learnability for pleasant (P) lists. Only, then, in the case of Experiment 2 does any doubt still remain. In the three other experiments the evidence is clear of greater learnability for the pleasant (P) lists.

Turn again to the table for the caffeine experiments. In Experiment 6 the excess in repetitions for the p lists does not seem great as compared with that in percentage of correct responses. In Experiment 7, on the other hand, it does. We would be inclined to urge that the figures for these two experiments combined would not disprove a slight tendency for greater learnability for the caffeine (P) condition.

Examining the table in the case of the efficient vs. inefficient experiments, we note decided evidence for greater learnability for the efficient condition. In three experiments, 10, 11, and 12, the percentages of correct responses are only equal, although the numbers of repetitions are decidedly greater for the p lists than for the P lists. In two other experiments, 8 and 13, the percentages of correct responses are only slightly greater for the p lists than for the P lists, although the numbers of repetitions are approximately twice as great for the former. In the one remaining experiment only, Experiment 9, is the evidence uncertain. Taking the six experiments as a whole, therefore, the figures point to a very decidedly greater learnability for the efficient (P) condition.

To sum up, in one of the three cases, caffeine vs. without caffeine, the evidence is inconclusive; in the other two cases, pleasant vs. indifferent, and efficient period vs. inefficient period, it is decidedly in the direction of greater learnability for the (P) condition.

Let us turn now to the figures for work. The following table includes the results of the work for all 13 experiments.

Before examining the table, we may draw attention to the fact that it is only in the figures for the experiments concerning caffeine vs. without caffeine and efficient periods vs. inefficient periods that we should expect a consistent difference, since it is only in these two sets of experiments that the contrasts could be expected to affect anything other than the immediate lists themselves. Obviously the contrast of pleasant vs. indifferent

	Exp.	*M Condition.*		*L Condition.*	
		Nos.	*Cons.*	*Nos.*	*Cons.*
	1	15.0	10.5	15.8	10.0
Pleasant vs. Indiff.	2	14.0	10.3	10.6	9.7
	3		6.4		7.1
	4		14.1		14.1
Normal vs. Distracted.	5	14.2	10.9	14.4	10.2
Caffeine vs. without Caffeine.	6		20.6		19.4
	7		21.0		19.4
	8	12.4		12.4	
	9	14.5		13.7	
Efficient vs. Inefficient.	10	11.1		11.3	
	11	13.3		12.3	
	12	17.0		14.3	
	13	19.4		16.7	

affects the lists only, as also that of normal vs. distracted attention. Turning to the table, we find among the four pleasant vs. indifferent experiments one, Exp. 3, in which the work averaged more for the indifferent lists; one, Exp. 2, in which the reverse was true; one, Exp. 4, in which the works are equal; and one, Exp. 1, in which the figures for the two kinds of work contradict one another. In Exp. 5, that of normal vs. distracted attention, the figures also contradict one another. The expected result, in short, of no consistently greater work for the M condition than for the L condition was obtained.

Examining the table as regards the caffeine vs. without caffeine and the efficient period vs. inefficient period experiments: in six out of the eight, the figures show more work for the M condition; in another, Exp. 8, equal work; and in one, Exp. 10, approximately equal work for the two conditions. It appears that the figures for work further justify the terms "More" and "Less Stimulating."[14]

In the next section we turn to a discussion of time values.

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[14] This review of the work figures has another significance. For, if it had appeared that more work had tended, generally speaking, to be accomplished in the L condition, then it might have been claimed that the greater inhibition found for that condition was the result of the greater work. This has already been touched upon in our discussion of individual experiments.

VI. Time Values.

In the present section we will briefly group together the values for the times of the correct responses. These were obtained for the caffeine vs. without caffeine and the efficient period vs. inefficient period experiments only. The figures are shown in the following table. The captions have the same meaning as in the previous sections.

		Caffeine.			Without Caffeine.	
		TA	T<2.0sec.		TA	T<2.0sec.
Exp. 6	P	4.5	9	p	6.3	7
n=48	W	6.0	9	w	6.1	2
		TA	T<1.4sec.		TA	T<1.4sec.
Exp. 7	P	1.8	20	p	2.3	16
n=72	W	1.9	7	w	2.7	5
		Efficient Hour.			Inefficient Hour.	
		TA	T<2.0sec.		TA	T<2.0sec.
Exp. 8	P	3.5	9	p	4.3	4
n=50	W	4.7	7	w	5.7	4
		TA	T<1.8sec.		TA	T<1.8sec.
Exp. 9	P	2.8	3	p	3.2	3
n=30	W	5.7	3	w	3.9	1
		TA	T<1.2sec.		TA	T<1.2sec.
Exp. 10	P	1.8	5	p	1.9	3
n=30	W	2.2	2	w	2.0	2
		TA	T<1.6sec.		TA	T<1.6sec.
Exp. 11	P	1.9	7	p	2.0	6
n=30	W	2.8	4	w	2.0	4
		TA	T<2.2sec.		TA	T<2.2sec.
Exp. 12	P	4.8	10	p	6.0	5
n=30	W	4.3	7	w	4.5	5
		TA	T<1.4sec.		TA	T<1.4sec.
Exp. 13	P	2.9	13	p	4.7	6
n=50	W	3.4	9	w	5.2	8

Let us examine the above table. Comparing the results for the passive lists, we note that in every case the mean time for p was longer than for P, and that in every case but one (Exp. 9), the number of short response times was consistently less for p than for P. This fact that *the times for the passive lists always tended to be longer for the Less Stimulating than for the More Stimulating condition* is important. It holds in spite of the fact that the percentages of correct responses were as big or bigger for the former than for the latter, and it therefore points to a real difference between the two conditions. It constitutes, therefore, a third reason for the designations of "More Stimulating and Less Stimulating."

Turning to the figures for the W and w lists, we note that in general both the average times and the numbers of short times indicate a tendency for longer times for these lists than for the passive lists. They present, in short, further testimony, in addition to that of the percentages of correct responses, of the inhibitory effect of work. When, however, we compare the results for the W and w lists with one another, we find that, in general, the evidence of longer times for the w lists than for the W lists is not quite as great as was that of longer times for the p lists than for the P lists. In only five out of the eight experiments was the mean time for w longer than for W, and in only six of the eight experiments were the numbers of short response times less for the former than for the latter; whereas in the case of the P and p lists we found in every case but one complete evidence of longer times for the latter than for the former.

This difference between the results for the work lists and for the passive lists is the opposite of what we might perhaps have expected offhand. For, since there was greater inhibition for the L condition, as shown by the greater drop in the percentage of correct responses from p to w than from P to W, we should have expected that if the p lists gave consistently longer times than the P lists, the w lists would have given *even more consistently* longer times than the W lists. Instead we found the opposite.

An explanation suggests itself. The length of time which a response may take and still be successful will not exceed a certain maximum. For, if the response does not come within a relatively short time, the subject abandons the attempt. This means that the weaker the association strengths become and *pari passu* the longer the response times, the less will a further increase in weakness affect the times. And we get such a situation as the present where the effect of the work seems to have been to wipe out to some extent the previous greater length of the response times for the L condition.

To sum up: We may consider that the time values are interesting primarily not because they add further testimony as to the greater inhibitory action of the L condition, but because, considering them for the passive lists alone, they point to a difference between the effects of the two contrasted, conditions which seems to be consonant with and to further amplify the difference found in the numbers of repetitions required and in the amounts of work accomplished.

In the next chapter we present a summary and discussion of our results.

CHAPTER V

SUMMARY AND DISCUSSION

Our results, briefly, are:

I. Pleasant lists, learned with caffeine, and lists learned in an efficient hour of the day (More Stimulating conditions) tended to be less affected by work, i.e., to show less evidence of retroactive inhibition, than did indifferent lists, lists learned without caffeine, and lists learned in an inefficient hour of the day, respectively (Less Stimulating conditions).

II. *Pleasant lists, lists learned with caffeine, and lists learned in an efficient hour of the day (More Stimulating conditions) all seemed to require fewer repetitions for the same amounts of learning than the respectively contrasted indifferent lists, lists learned without caffeine, and lists learned in an inefficient hour of the day (Less Stimulating conditions).*

III. *The work accomplished with caffeine and in an efficient hour of the day (More Stimulating conditions) tended to be greater than that accomplished without caffeine and in an inefficient hour of the day (Less Stimulating conditions).*

IV. *Lists learned with caffeine and in an efficient hour of the day (More Stimulating conditions) tended in the case of the passive lists to have shorter response times than lists learned without caffeine and in an inefficient hour of the day (Less Stimulating conditions).*

V. *Lists learned under normal attention and lists learned under artificially distracted attention differed only as to the numbers of repetitions required for equal learning.*

To explain the differences between the inhibition effects in the More and Less Stimulating conditions, two hypotheses, and only two at present, suggest themselves. They both originate from the longer average response times for the passive lists of the L condition.[1]

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[1] It is, of course, unfortunate that the times were not measured for the pleasant and indifferent lists, but we are assuming that what held for the other pairs of contrasts would have held also for them.

The first hypothesis would assume that this longer time corresponded to relatively more just supraliminal and relatively fewer "over-learned" associations for the L conditions than for the M conditions. Since it already seems to have been established[2] that just supraliminal associations tend to be relatively more affected by retroactive inhibition than are stronger associations, the desired explanation results.

It will be noted that this hypothesis assumes that the M condition for some reason produces less "even" learning than the L condition; that, in other words, in the M condition the easy parts of the list tend to be learned relatively speaking much sooner than the hard parts. Just why, however, such a difference should exist between the effects of the two conditions would be a question for further hypothesis and examination.

Our second hypothesis, on the other hand, assumes that the longer average time for the L condition is not due to any difference in the "evenness" of learning, as such, but to a fundamental neurological difference in the nature of the association bonds formed in the two conditions, such that, given bonds of equal strength, those in the L condition would tend inherently to take a longer response time, and to be more affected by retroactive inhibition than those of the M condition. It would assume, in short, that the underlying neurological conditions which cause the fewer repetitions, the greater accomplishment of work, and the above mentioned shorter response time for the M condition would also have the further effect of causing a less great susceptibility to retroactive inhibition on the part of the association bonds formed in this condition. This second hypothesis seems much the more suggestive and interesting.

At present, however, we have no basis for choosing between the two hypotheses. We simply present them as the only two possible assumptions which occur to us, and leave it for future work to determine between them.[3]

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[2] Heine advanced evidence to show that weak associations are relatively more affected by retroactive inhibition than strong ones. Op. cit., pp. 211-225. See also above, pp. 6-7.

[3] Another investigation is already in progress which, it is hoped, will furnish such a decision.

One final question: To what extent do our results throw light on the opposition between De Camp's results and those of Müller and Pilzecker and of Heine? To answer this question we must search for possible outstanding differences between the conditions of the two sets of experiments. Such a careful examination reveals the following points: 1. As work De Camp used some form of mental work other than memorizing;[4] the German experiments used memorizing of other material usually of a quite different sort from the original material. 2. De Camp presented the two syllables of each pair simultaneously, with a wait between each pair, and the time per revolution of the list was relatively great, about 23.7 sec.[5] Müller and Pilzecker and Heine presented all the syllables of the lists successively. The interval between the last syllable of one pair and the first syllable of the next was the same as that between the first syllable and the last syllable of the same pair. The total time of presentation was short, varying from 7.2 sec. to 10.5 sec. per single revolution.[6] 3. De Camp used different subjects from those used by the German experiments, and it is very possible that he also used a different working hour for carrying on his experiments.

Let us now consider these differences from the point of view of any light thrown on them by our results. As regards the first, we used further memorizing just as did Müller and Pilzecker and Heine. Yet we did not find inhibition in all cases. When the learning conditions were More Stimulating, evidences of inhibition were in some cases wholly lacking, and in others much reduced. It would seem, therefore, that memorizing as work does not necessarily mean inhibition. Hence the greater evidence for inhibition obtained by the German investigators is probably not to be attributed entirely, if at all (as De Camp seems to suggest), to the fact that they used further memorizing as work, whereas De Camp used cross-multiplication.

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[4] With the exception of Exps. VIII in which physical work was used (see above, p. 9).

[5] De Camp, op. cit., p. 15. As against this difference is to be reckoned, of course, the fact that De Camp used 14 syllable lists, whereas the German experimenters used none longer than 12.

[6] Müller and Pilzecker, op. cit., pp. 180-190; Heine, op. cit., pp. 187-197, 217-223.

As for the second difference between De Camp's experiments and those of Müller and Pilzecker and of Heine—the mode and rate of presentation—a similar argument holds. Our conditions were again closely similar to those of the German investigators. Yet we did not find inhibition in all cases.

The last differences remain to be discussed; that of different subjects and that of a possible difference in hours of experimenting. These might, we believe, afford a partial explanation. They might be analogous to our More and Less Stimulating conditions. As regards a difference in subjects, our experiments, it is true, do not directly bear. But from the actual carrying of them out, we have become convinced that certain subjects exhibit inhibition much more readily than others; that, in short, they are always "More Stimulated" than others. From a purely speculative point of view this seems a reasonable assumption; viz., that the differences which exist between efficient and inefficient hours and between being with caffeine and without caffeine in the case of any one subject may be duplicated in those existing between subjects. Making such an assumption as regards De Camp's subjects as compared with those of Müller and Pilzecker and of Heine, and assuming further that the hours of the day chosen in some of De Camp's experiments were more efficient than those chosen by the German investigators, we have an explanation of the contradiction between their results.

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DESCRIPTION OF AN UNUSUAL CASE OF PARTIAL COLOR BLINDNESS

BY

Mabel Clare Williams

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Introduction

The subject of this study will be referred to as J. H. He was a student in the University of Iowa during the year 1914-1915. His matriculation card gives as the place and date of his birth: Edinburgh, Scotland, April 27, 1890. He is of medium height and weight, in good physical health, and shows no evidence of disease or condition that would in any way influence his vision. He does not use tobacco, alcohol, or other drugs. His eyes are light blue in color with slightly bluish sclera, well set and wholly "normal" in appearance. For constant use he wears spectacles with peritoric lenses, spheres +1.25 dioptres over each eye, fitted in London without cycloplegic. Dr. Heard, physician in charge of the ophthalmic clinic in the College of Medicine in the University of Iowa, re-examined J. H.'s eyes, also without cycloplegic, and reports "vision right eye 6/3, left eye 6/3, showing him to be a hyperope since he reads at 6 meters what he should read at 3, and he reads this equally well with the +1.25 spheres. His accommodation is evidently very active. Since he refused a cycloplegic, this is only a measure of his manifest, not his latent, hyperopia. Ophthalmic examination reveals no astigmatic error. Fundi those of the typical hyperope. Retina granular in appearance due to pigment. Arteries not tortuous. Media clear."

Little family history of a satisfactory sort is available. His father, who died when J. H. was fifteen years old, was known to be color blind (letter from his widow, the mother of J. H. and herself not color blind) but there is nothing to indicate the type. Of the three brothers of J. H., two had probably normal color vision and in general appearance are said to have resembled the mother; while the third brother, A. H., and J. H. himself, resembled strongly the (color blind) father and were themselves color blind. The brother A. H., recently dead, apparently exhibited the same sort of color defect as J. H. As boys and young men together they often compared colors of objects and agreed always with each other but not with the other two brothers, only one of whom is now living. The two sisters are not color blind so far as J. H. knows. J. H. is the only member of the family who has been in this country.

J. H. has at all times been a most satisfactory observer. He was very careful and painstaking and unusually accurate, due in part perhaps to extensive training in biology and chemistry. He has done much microscopic work. Considering the fact that he has never been shown or told any of the results of the experiments even to the present time, his coöperation and willingness are all the more praiseworthy. It is therefore most pleasing to the writer to make public acknowledgement of indebtedness to him and to thank him. He began the experiments with the pre-established conviction that he was blind to blue and yellow, and was allowed to continue in that belief without discussion.

Attention was first called to the case in March 1915 through a mutual friend, Mr. C. J. Knock, fellow in the department of psychology at Iowa. It was noticed that only two color names were used, "red" and "green", and that "red" was applied indifferently to reds and yellows and "green" to greens and blues. There has never been any noteworthy variation from this throughout the whole period of experimentation. In connection with hospital work, he once had to diagnose with the attending physician a case of "yellow jaundice". The patient looked "red" to him and very queer. He thought she must be an American Indian, but the features were not right and she had light hair. "Her skin and eyes were red and she was a funny looking woman."

Experimental work of a preliminary sort was begun in the Iowa Psychological Laboratory on March 5th and continued at frequent intervals until June, when J. H. had suddenly to leave. Fortunately he was again available for study two weeks in December, 1915. Since the resources of the Iowa Laboratories had been practically exhausted and it was now advisable to work with spectral light, the writer went to Chicago to canvass the situation there. Professor Carr at that time suggested that the best opportunity for continuing the work was to be found in the Nela Research Laboratory of the National Lamp Works of the General Electric Company at Cleveland, Ohio. Accordingly, invitation was sought from the Director of the Laboratory, Dr. E. P. Hyde, and most cordially extended by him. The writer went to Cleveland early in December to prepare in advance for J. H. who arrived from Missouri on December 19th and remained until the night of January 1st, 1916. Traveling expenses for both were generously provided from the research funds of the Iowa Graduate College.

At the Nela Research Laboratory little could have been accomplished in so short a time without the considerate aid of Dr. H. M. Johnson and Mr. M. Luckiesh, to both of whom the writer is most deeply indebted. Dr. Cobb, Dr. Troland and other members of the staff contributed in less extensive but very important ways. Every facility possessed by the Laboratory was lent unreservedly. A valuable instrument (Hilger constant deviation wave-length spectrometer) was borrowed from Dr. Dunlap of Johns Hopkins and filled an immediate need.

The report of this case, though apparently extensive, should be regarded as a preliminary survey; and it is hoped that at some future time the study may be continued at the Nela Research Laboratory. The color names as used by J. H. have been quite disregarded. Control observers, usually three in number, were used in all tests where relative values only were obtainable. For the most part the several experiments are reported in their chronological order. The tests have all been conducted by the writer and are reliable to the extent claimed.

Color matching. (*Colored worsteds*)

A large well-mixed assortment of worsted skeins of many colors was spread out in good day light, on a table, over a large square of grey cloth. These skeins were not numbered and will be referred to by color only. No color names were used by examiner or subject.

(A) *Red* standard. A rich fairly dark red skein was handed to J. H. and he was asked to select from the pile all those skeins which resembled it in color but not necessarily in brightness. He selected out all reds and yellows, some sixteen skeins in all. He was then asked to re-sort these selected skeins according to two samples, the original red and a good yellow which he had included as a match for the red. He tried this, but gave it up as impossible.

(B) *Green* standard. Following the same procedure he selected to match the green sample thirty-two blues and greens of varying brightness and saturation. No red or reddish skeins were chosen. Given two samples, green and blue, and asked to re-sort his selections into two piles he again failed.

(C) *Yellow* standard. J. H. selected to match the yellow skein, the same skeins which he had sorted out to match the red and which had been returned to the main assortment. He added however a few more reds and yellows.

(D) *Blue* standard. The matches for the blue were identical with those for the green sample.

(E) *Grey.* Without sample, he was asked to select some "greys". Fifteen skeins were chosen, five of which were nearly true greys, eight were tans, and two were brown.

Color recognition. (*Nagel cards. Fifth edition*)

The available set of cards was old and somewhat soiled and perhaps faded. The results of the test should not be too rigidly interpreted. In the first four experiments (A, B, C, D) the regular procedure was followed.

(A) Select the card with red or reddish dots: A 12, A 6, A 1 were selected in the order given.

(B) Only red spots: A 3, and possibly A 15. He was not sure about A 15.

(C) Only green spots: A 5, A 13. He called the greyish spots on A 13 "green."

(D) Only grey spots: A 6. He also accepted A 9 after his attention was called to it and indicated the true grey spots on A 6 when asked to do so.

(E) For J. H., card B 1 consists of "plain red" (the shades of yellow) and "dark red or brownish".

(F) On card B 2 all the spots are "red, but the bright ones are redder; the others are brownish".

(G) Point out all the A cards with red spots: 6, 15, 12, 14, 3, 1, 11 (the yellow spots), 7, 16, 8, 10. Of the remaining A cards, "5 is green, 4 has green spots (correctly indicated), 13 is green with the greys showing a trace of green; 9 has shades of very dark green."

Color equations. (*Color mixing by rotation*)

Disks of two sizes, 5.8 and 9.6 cm. radii, were cut from Hering colored papers: red (old No. 1), green (old No. 7, new No. 9), blue (old No. 10, new No. 13), yellow (old No. 5, new No. 5), and black and white. Care was taken to guard against fatigue and an exact match was insisted upon. A small disk of single color was mounted over large disks in combination and the following equations were secured.

(A) Red 360° = yellow 270° + black 90°

(B) Green 360° = blue 226° + white 134°
(C) Blue 360° = green 132° + white 21° + black 207°
(D) Yellow 360° = red 257° + white 45° + black 58°

The four colors were then combined in pairs to match grey (black and white).

(E) Blue 279° + red 81° = white 51° + black 309°
(F) Green 222° + red 138° = white 111° + black 249°
(G) Yellow 173° + blue 187° = white 150° + black 210°
(H) Yellow 167° + green 193° = white 129° + black 231°

In the three experiments thus far described, the results of the Nagel test seem not to be very decisive. In the conditions under which they were conducted, their chief significance is in indicating that some defect in color vision is obviously present. Too much stress is placed upon the color names which J. H. can apply successfully to red and green. The worsted test is suggestive and quite corroborated by the color equation tests. J. H. evidently has his color system reduced to two processes: that which conditions what he calls "red" and applies consistently to both red and yellow; and that which conditions what he calls "green" and applies consistently to green and blue. Real red and green are not confused nor are yellow and blue. These color processes are apparently physiologically antagonistic since a match for grey may be produced by proper combinations on the color wheel. The darkest grey is matched by blue (called "green") and red (called "red"); the next lighter grey is matched by green ("green") and red ("red"); the next lighter by yellow ("red") and green ("green"); and the lightest grey by yellow ("red") and blue ("green"). One would naturally expect the combination of yellow and green to require the most luminous grey as its equivalent. This discrepancy is probably in part due to the fact that only one trial was made and, in spite of frequent rests, fatigue may have entered, as all four of the grey equivalents were made at one rather tedious sitting and the yellow-green combination was tried last. Subsequent experiments (luminousity curves) show that for day-light adaptation, green is much nearer to spectral yellow in luminousity than is blue.

Color sensitivity. (*Colored rings on white rotating disks*)

This is essentially the same test described by Hayes, (1). The disks, 9.6 cm. in radius, were somewhat larger than those made by Hayes. They were cut from white bond paper, several thicknesses of which were used to avoid transparency. The rings of color (Hering papers red, green, yellow and blue as previously described and grey No. 9 from the Hering 50 greys) were 1 cm. wide, and were pasted smoothly midway between the center and the periphery of the disks. It was not possible to keep all the four colors and grey on the wheel at once[1] so each color was paired with the same grey and the observer was asked to decide whether a given color or grey was exposed. More foreknowledge on the part of the observer was implied here than in Hayes' tests and the threshold values are probably on that account lowered. Chance determined whether a portion of a colored ring or of the grey should be exposed. Records were obtained also from three control observers, Dr. R. H. Sylvester, Mr. C. J. Knock, and Mr. P. J. Sodergren, all members of the psychology department at Iowa. The results which represent the minimal exposure of color necessary for recognition, are stated in degrees. Ten determinations were made on each color paired with grey for J. H. and five for the controls. The averages and mean variations are presented in Table I.

TABLE I

	J.H.		R.H.S.		C.J.K.		P.J.S.	
	Ave.	m. v.	Ave.	m. v.	Ave.	m. v.	Ave.	m. v.
Red or	11.2°	1.8°	2.7°	0.2°	2.0°	0.2°	3.0°	0.8°
Grey	12.0	0.8	2.6	0.7	4.0	0.6	3.4	0.5
Green	9.1	0.9	2.5	0.0	3.2	1.4	3.6	0.5
Grey	11.2	1.6	2.7	0.2	2.1	0.7	3.6	0.5
Blue	12.3	2.5	23.0	5.6	2.3	0.4	6.2	1.8
Grey	18.3	5.0	6.8	2.7	4.0	1.6	4.6	1.6
Yellow	36.2	4.2	4.2	0.9	4.1	1.4	5.6	1.3
Grey	14.0	1.4	4.0	0.4	3.7	1.2	4.1	1.1

[1] This was actually done for J. H. however, and when he did not know what to expect, red was recognized at 13°, green at 21°, yellow ("red") at 31°, and blue ("green") at 33°. Grey was called "dirty white" at 10°.

The results of this test, which should be regarded as having relative value only, indicate a lesser degree of sensitiveness for the color stimuli in the case of J. H., as compared with the three control observers. The only exception to this is with the blue for R. H. S., whose readings for this color scattered widely and were very uncertain.

Color discrimination. (*The Lovibond Tintometer,* 2)

This instrument offers a ready means for measuring color sensitivity and discrimination when pure color stimuli are not demanded. The colored glass ray filters which are provided with the instrument are carefully standardized according to an arbitrary scale, and the units are recoverable, convenient and fairly permanent. The filters are not even approximately monochromatic, however, although to the eye the transmitted hues appear to be fairly pure.

The tintometer was set up where north daylight fell directly upon its windows. A ground-glass strip was placed between the slips and the source of light as an aid in securing a homogeneous surface. It was necessary to compound the glass slips in order to secure the proper increments from the available assortment. Four or even five slips could be bound together quickly with a rubber band and handled as easily as one. Each slip doubtless cut down the intensity of the transmitted light, for even clear glass will do this to the extent of 8%. A clear or white glass was always used in connection with the standard to help equalize this effect. Lateral light was excluded from the observers' eyes by means of the hood of the instrument. The colors were viewed with both eyes open.

A simple form of the method of constant stimuli was found satisfactory. Two slips, say red 10, were placed in two adjacent windows of the instrument, then, after a few minutes of skirmishing, the increment was found which when added to one of the windows containing red 10, made it just perceptibly "redder" than the other. A difference which yielded 80% of correct judgments was regarded as the approximate threshold. This increment was then fixed to one of the red standard slips and one hundred comparison judgments were made. The right and left positions of the two stimuli were determined in accordance with a chance key already prepared. The observer either closed his eyes or looked away while the slips were being shifted and always pronounced judgment quickly without staring at the colors. From the number of correct judgments and the size of the increment, the discrimination threshold which probably would yield 75% of correct judgments was computed by means of the well known Fullerton-Cattell table.

In Table II are given: the initials of the observers, J. H. and three controls; the composition of the two stimuli compared, St. 1 and St. 2; the threshold increment in terms of arbitrary tintometer units; the percentage of correct judgments in one hundred trials; and the probable threshold for each of the four colors. It should be remembered that J. H. identifies yellow with red and blue with green.

TABLE II

Observer	St. 1	St. 2	Incr.	%	75%
		RED			
J.H.	R 10 + clear	R 10 + 5	5.0	85	3.20
R.H.S.	R 10 + clear	R 10 + .2 + .1	.3	83	.21
C.J.K.	R 10 + clear	R 10 + .1 + .1	.2	83	.14
P.J.S.	R 10 + clear	R 10 + .1	.1	83	.07
		GREEN			
J.H.	B 10 + Y 10 + B5 + Y5	B10 + Y10 + B10 + Y10	5.0	72	5.80
R.H.S.	B 10 + Y 10	B10 + Y10 + B1 + Y1	1.0	89	.60
C.J.K.	B 10 + Y 10 + clear	B10 + Y10 + B.3 + Y.3	.3	88	.17
P.J.S.	B 10 + Y 10 + clear	B10 + Y10 + B.2 + Y.2	.2	83	.14
		BLUE			
J.H.	B 10 + clear	B 10 + 1 + 1 + 1	3.0	75	3.00
R.H.S.	B 10 + clear	B 10 + .5	.5	81	.39
C.J.K.	B 10 + clear	B 10 + .5	.5	86	.30
P.J.S.	B 10 + clear	B 10 + .1	.1	76	.10
		YELLOW			
J.H.	Y 10 + 1 + 1	Y 10 + 5 + 1	4.0	79	3.30
R.H.S.	Y 10 + clear	Y 10 + .3 + .2	.5	81	.39
C.J.K.	Y 10 + clear	Y 10 + .1 + .1	.2	64	.37
P.J.S.	Y 10 + clear	Y 10 + .3 + .2	.5	87	.30

In the case of J. H., St. 1 is slightly different from that of the control observers for the colors yellow and green. An attempt was made to use for him the yellow which could not be distinguished from red 10, which was yellow 10 + 1 + 1. Green was somewhat difficult to secure, since no green slips were available, and blue and yellow had to be combined for it. However, a very good green resulted from this combination; and the green which matched blue 10 was compounded from Y 10 + B 10 + Y 5 + B 5 + Y 1 + B 1. These six slips were too thick when bound together to fit the receiving stalls of the tintometer, so the last two were omitted, and the four designated in the table retained.

These tests with the tintometer indicate that J. H. has a decidedly higher discrimination threshold than the normal observers. It is however questionable whether he is really judging depth of color at all; the probability is that some other factor, perhaps luminosity, served as a criterion. To what extent this is also true of the other observers is uncertain; they are at any rate, more sensitive to color than J. H. and, under identical conditions, make better discrimination records. The results, even as they stand, are too favorable for J. H., (see his hue discrimination records, p. 20 f).

Color fields

A recent model of the Meyerowitz self-recording perimeter was secured and fitted with new stimulus patches 9 cm. square, cut from the four Hering colored papers and white. The self-recording device was discarded and the records read in degrees directly from the arms. The color carriers were moved at such a rate that approximately ten seconds were required for one determination. The unused eye was comfortably bandaged. A color, not known to the observer, was moved inward from the periphery and the position noted where it first was named correctly. Two determinations for each of the five stimulus patches were made in each of the four cardinal meridians for each eye, with J. H. and the three regular control observers. J. H., of course, reported only two colors and white. His records again have relative value only, and achieve their significance when compared with those made upon observers with normal[2] color

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[2] C.J.K. has complete central scotoma in his right eye and perhaps slight color weakness.

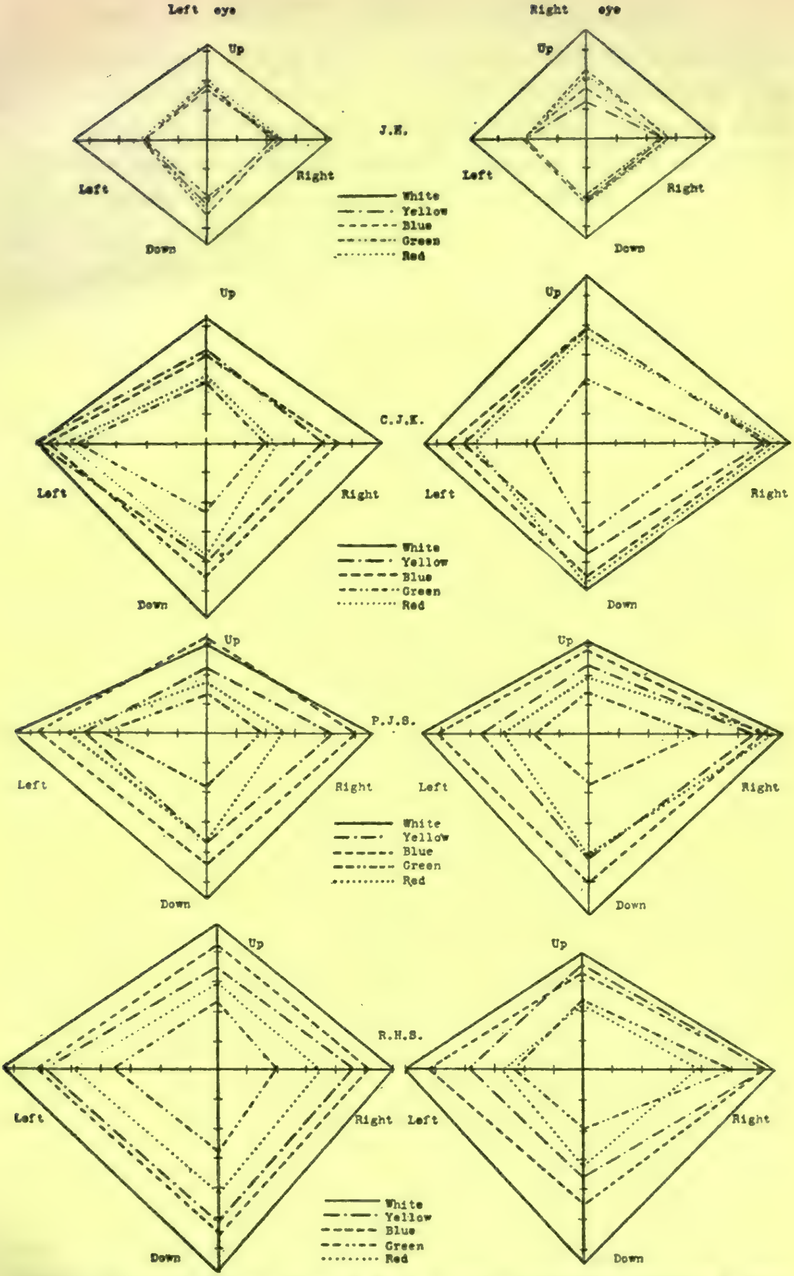

FIG. 1. Visual fields of J.H. and three control observers. Drawn to same scale. Units on axes = 10°.

vision under identical conditions. The results are presented here only in graphic form,[3] Fig. 1, but the curves are drawn to the same scale and may be directly compared. The curves show very close general agreement among the three control observers; all are rather typical. J. H., on the contrary, shows marked contraction of both his color fields and his field for white. The fields are so small that the familiar limiting in certain meridians by the interference of the nose, brow and cheek does not occur, and even the boundaries for white are almost symmetrical. The color fields are very small and practically coincident.

Relative stimulating values of the different wave lengths[4] (*Spectral luminosity*)

The relative stimulating values of the different wave lengths were sought for by means of a Hilger spectroscope of the fixed arm, constant deviation type, combined with a Whitman disk so as to form a flicker photometer or a direct comparison heterochromatic photometer as desired. The essential feature of the apparatus was recently described by Ives (3) and others. The reflecting surface of the Whitman disk was covered with magnesium oxide, so that the distribution of energy among the wave-lengths of the visible spectrum approximated that of the source of illumination on the disk. In the tests made under light adaptation, this source was a tungsten lamp having a "color temperature"[5] of 2327° Absolute. In the tests under dark adaptation, the source was a similar but smaller lamp giving a color temperature of 2355° Absolute. The brightness of the disk was determined by the position of the lamp and was kept constant at 32.8 candles per square meter in the work under light adaptation, and at 0.086 candles per square meter in the work under dark adaptation.

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[3] In view of the great length of many of the tables of values in this report, it has been deemed unnecessary to present the records in both graphic and tabular forms. The numerical values are systematically tabulated and on file and may be obtained from the writer by any one who may perchance wish them.

[4] The descriptions of the apparatus used in the succeeding experiments are substantially those very kindly furnished by Dr. H. M. Johnson of the Nela Research Laboratory, at which place most of these experiments were conducted.

[5] The color temperature of an incandescent filament is the temperature of a black body giving the same distribution of energy among the different wave-lengths as does the filament under the given conditions. This datum being specified, the spectral character of the radiation emitted by the source may be readily ascertained from well known formulae.

The observed field, as limited by a suitable diaphragm, was circular in form, and subtended a solid visual angle of 2.4°. It was observed through an opening 1 mm. in diameter, placed in the plane of the image of the collimator-slit formed in the minimally deviated wave-length. The observer's eye was about 1 cm. from the aperture, which is as close as his eye-lashes would permit. In the tests by the method of direct comparison, the Whitman disk was stationary, and turned so that one of its radial edges bisected the field vertically. The left half of the field as observed was a portion of the disk, illuminated by tungsten light. The right half was a portion of the prism illuminated in monochromatic light, the wave-length of which was determined by the angular position of the prism. The limiting diaphragm was in all cases completely filled with light. In the tests by the flicker method, the entire circular field was illuminated successively by colorless and monochromatic light. The surroundings of the field were dark except for light scattered in the optical system and in the refractive media of the eye.

The source of homogeneous light was a tungsten lamp. In the tests by both the flicker and direct comparison methods, the spectrometer lamp occupied a fixed position with reference to the collimator-slit. In the direct comparison method, the observer sought an equation of the brightness of the colored portion of the field with that of the disk, by himself adjusting the width of the collimator-slit, controlled by a micrometer screw, with scale reading directly to the 0.01 mm. The distance between the lamp and the slit was increased to secure lower illumination for the tests under dark adaptation and a ground-glass surface was placed between the filament and the collimator-slit, to give uniformity of brightness over the colored portion of the field and further to reduce illumination.

In the experiments according to the flicker method, the speed of the disk was controlled, within limits, by means of resistance in the motor circuit.

The entire system was covered with black felt, and the eyes of the observer were protected from stray light from the lamps. Day-light was excluded from the room. In the tests under light adaptation, the general illumination of the room was from four 150 watt "Mazda C-2" lamps in an overhead fixture. These lamps have tungsten filaments in a gas-filled bulb, the selective absorption of which is such as to transmit light approximating that of afternoon sunlight in spectral character. In the work under dark adaptation, the general illumination was eliminated and fair dark-room conditions were obtained. The observer remained in the darkened room about twenty minutes before beginning the experiments and kept his eyes closed except during the short interval when making the comparisons.

The flicker settings under dark adaptation became very uncertain except for the middle regions of the spectrum, perhaps because the speed of the motor was not variable within sufficiently wide limits.

In making the settings, a definite procedure was followed. The observer himself turned the micrometer which varied the slit-width which controlled the amount of light admitted to the prism of the spectrometer. The scale readings were all made and recorded by the experimenter. Beginning at 720 $\mu\mu$, five settings were made at regular intervals of 20 $\mu\mu$ until 420 $\mu\mu$ was reached. Then the spectrum was similarly surveyed in the reverse order. Of the ten readings thus secured for each wave-length selected, five were made with the luminosity varying from less than that of the colorless comparison field, to equality, and the other five varied from greater luminosity to apparent equality. These two directions of approach alternated regularly in both the direct comparison and the flicker methods, which themselves alternated, five direct comparison readings being made, then five flicker readings. Ten readings, taken in the double fatigue order, were thus secured for each 20 $\mu\mu$ interval of the spectrum within the limits indicated, for both the direct comparison and flicker methods. With otherwise identical procedure, readings were obtained for both photopic and scotopic vision for each eye of J. H. separately, and for the right eye of three control observers, Dr. L. T. Troland, Mr. Everett Schmidt (a graduate of one of the Cleveland technical high schools), and from the writer.

(A). *Photopic luminosity.* (*Daylight adaptation*)

The records are given in graphic form in Figs. 2, 3, 4, 5 and 6, and represent the reciprocals of the slit-widths in mm. plotted against the ordinates, and the wave-lengths as abscissae. The result is a luminosity curve for a prismatic spectrum of tungsten at a temperature of 2385° Absolute.

J. H., for whom such work was new, had some difficulty at first with the direct comparison method and the results for this method never became so constant as for the flicker method. The mean variations (not presented) show this very clearly. His curves for the flicker method bear a close general resemblance to those of the control observers and also those which have been published by Ives and other investigators. In his direct comparison curves, there is a noticeable break at 560 $\mu\mu$; here the slit was opened much wider than for the wave-lengths immediately preceding and following, 540 $\mu\mu$ and 580 $\mu\mu$ respectively. This is probably due to the fact that there is an achromatic or neutral band in this region of his spectrum, near 560 $\mu\mu$, and he apparently opens the slit wider in the effort to admit color. For the flicker method this does not occur, as the whole field then becomes homogeneous and he is not directly conscious of equating two separate fields.

J. H.'s descriptive comments about the various colored lights are interesting and are given here in his own wording as they were recorded during the progress of the experiment.

720 $\mu\mu$: "Deep red."
700 $\mu\mu$: "Red; good deep bright red."
680 $\mu\mu$: "Nice bright red."
660 $\mu\mu$: "Good bright red."

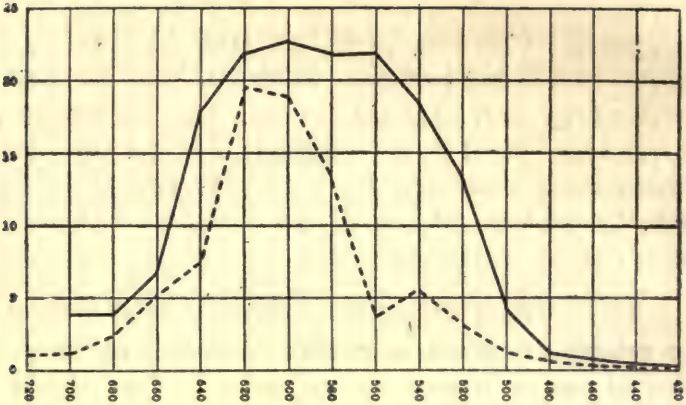

FIG. 2. Photopic luminosity curve for J. H. Right eye. - - - - - = direct comparison, ——— = flicker method.

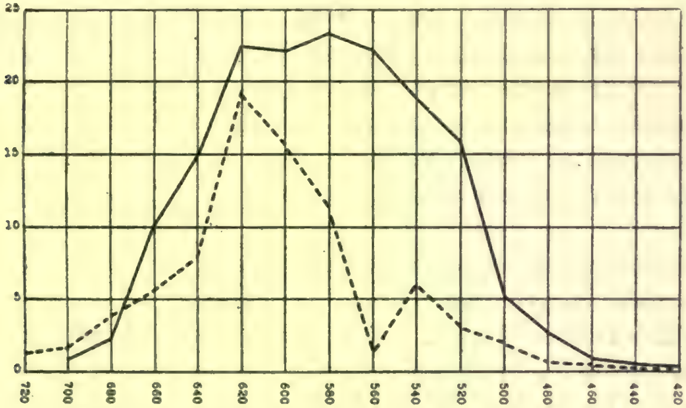

FIG. 3. Photopic luminosity curve for J. H. Left eye. - - - - - = direct comparison, ——— = flicker method.

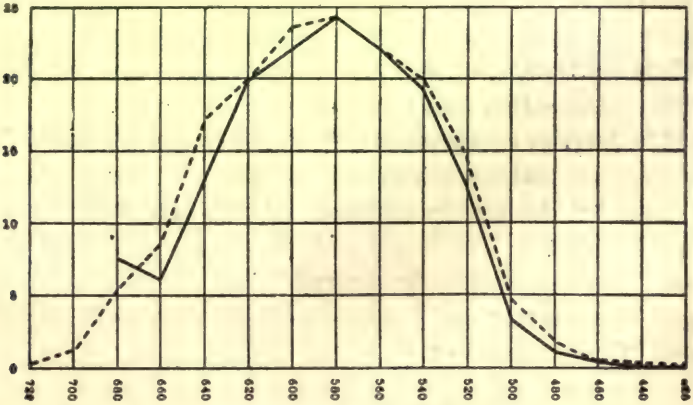

FIG. 4. Photopic luminosity curve for L. T. T. Right eye. - - - - - = direct comparison, ——— = flicker method.

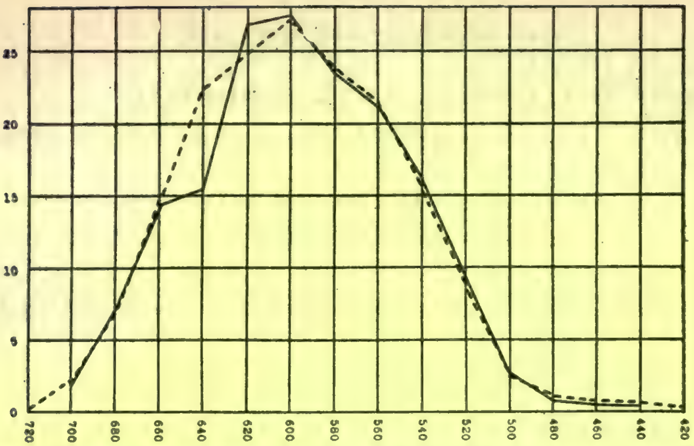

FIG. 5. Photopic luminosity curve for E. S. Right eye. - - - - - = direct comparison, ——— = flicker method.

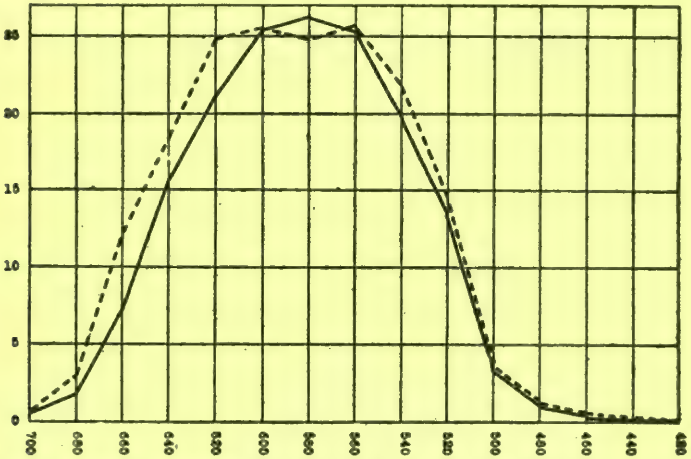

FIG. 6. Photopic luminosity curve for M. C. W. Right eye. - - - - - = direct comparison, ——— = flicker method.

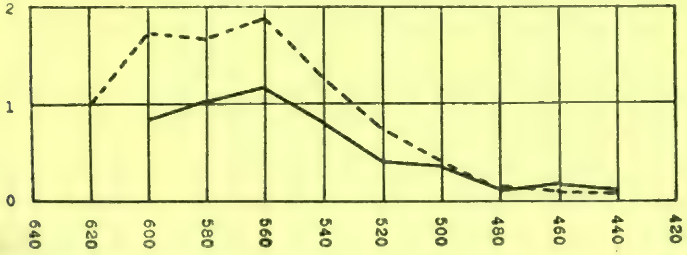

FIG. 7. Scotopic luminosity curve for J. H. Right eye. - - - - - = direct comparison, ——— = flicker method.

640 μμ: "Red; lighter but not particularly light."
620 μμ: "Pale red, even when reduced to just visible intensity."
600 μμ: "Light red."
580 μμ: "Faint reddish; lots of light in it."
560 μμ: "Pale red; very pale indeed." On another occasion, "Light green."
540 μμ: "Light green; not the same as before; quite a bit of green in it."
520 μμ: "Green; an unsaturated green."
500 μμ: "Deep green."
480 μμ: "Good saturated green."
460 μμ: "More saturated green than ever. A good deal more so than the last one."
440 μμ: "Dark saturated green; a little darker than the last one."
420 μμ: "Much the same as the other one; a dark saturated green; does not seem to be different."

(B). *Scotopic luminosity.* (*Dark adaptation*)

The results are presented graphically in Figs. 7, 8, 9 and 10. The curves represent the luminosity of a prismatic spectrum at a color temperature of 2100° Absolute. The notation is the same as that for the photopic curves, but they are drawn on a slightly different scale; had the same scale been used the curves would have been too flat. All the observers, except perhaps L. T. T., who alone had had extensive practice in photometry, had much difficulty with both the direct comparison and the flicker determinations. It is doubtful whether adaptation was complete enough to show the Purkinje effect.[6] With both the direct comparison method and the flicker method, the spectrum was not so luminous for J. H. as for the controls; he kept the slit opened much more widely. His achromatic band, near 560 μμ, was for him the most luminous part of the spectrum, the place where he most nearly closed the slit. This is just the reverse of the situation in the photopic adaptation curve with

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[6] L.T.T. exhibits to a slight degree with the flicker method the "reversed Purkinje effect" described by Ives (4). The same effect is suggested in the case of J.H., and to a lesser degree with E.S.

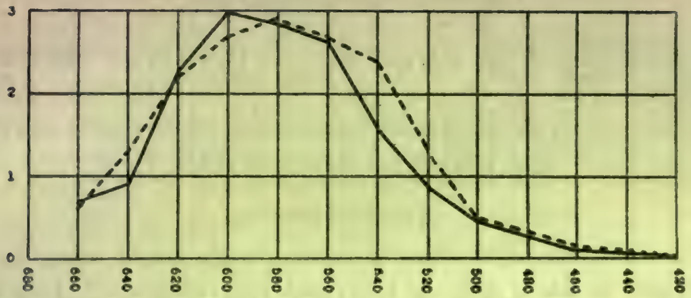

FIG. 8. Scotopic luminosity curve for L. T. T. Right eye. - - - - - = direct comparison, ——— = flicker method.

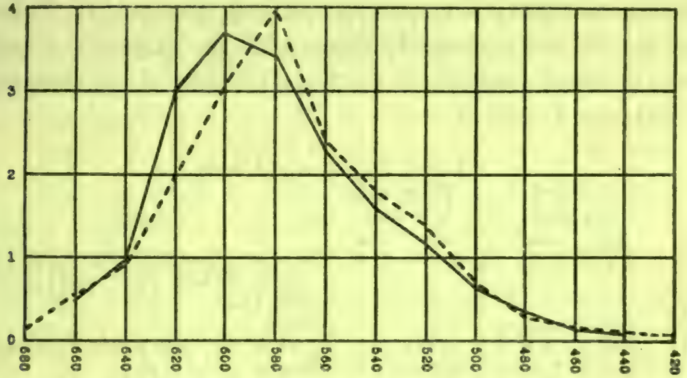

FIG. 9. Scotopic luminosity curve for E. S. Right eye. - - - - - = direct comparison, ——— = flicker method.

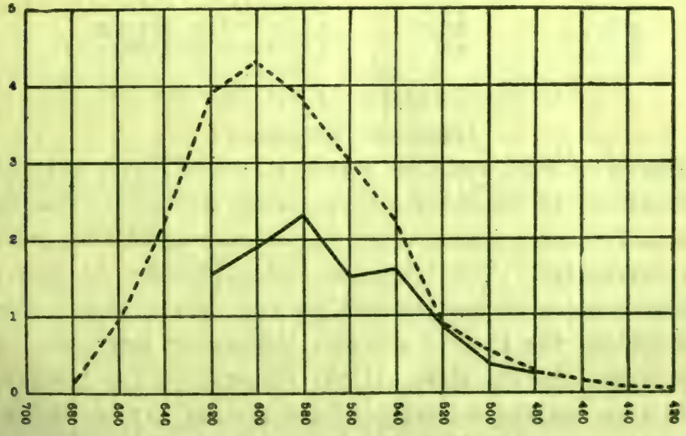

FIG. 10. Scotopic luminosity curve for M. C. W. Right eye. - - - - - = direct comparison, ——— = flicker method.

the method of direct comparison. It is probable that he saw very little if any color in any part of the spectrum with this low illumination, so the suggested explanation for the wide slit-width for 560 μμ in light adaptation does not apply here.

Spectral limits

No very extensive measurements were made since it was necessary to know only in a general way whether J. H.'s spectrum was shortened, especially at the long wave end. It may be said that, under the most favorable conditions, he reported color approximately between 750 μμ and 400 μμ. In Table III some records are presented; those with the carbon arc and the Nernst filament were made by Mr. Helmick of the department of physics at Iowa.

TABLE III—*Spectral limits*

	Red-end		Violet end		
	Ave.	m. v.	Ave.	m. v.	Source
Obs.	μμ	μμ	μμ	μμ	
J.H.	740.0	3.7	406.8	.9	Tungsten lamp, Hilger spectrometer, ruby Schott Jena glass over slit for red.
M.C.W.	767.5	4.3			Same.
J.H.	661.3	6.0	461.9	7.7	Carbon arc and ordinary prism.
R.H.S.	693.0	5.0	428.0	4.0	Same.
C.J.K.	701.0	8.0	411.0	4.0	Nernst filament.
P.J.S.	682.0	8.0	430.0	4.0	Carbon arc.
M.C.W.	712.0		404.0		Nernst filament.
M.C.W.	704.0		384.0		Carbon arc.
Norm	723.0		397.0		(As stated by Parsons.)
Norm	760.0		396.0		(As stated by Watson.)
Norm	800		400		(As stated by Köllner.)

Threshold differences for wave-length
(*Hue discrimination*)

These tests were made by means of two Hilger wave-length spectrometers of the fixed arm, constant deviation type, set up as monochromatic illuminators with a Koenig-Marten polarization photometer. The telescope and collimator of one spectrometer were interchanged and the two spectrometers were so mounted that the axes of the two collimators intersected at an angle of 90° in the plane of the filament of the lamp which served as a common source, and the axes of the two telescopes similarly intersected a short distance in front of the slit of the

Koenig-Marten photometer. The source was a tungsten filament in a gas-filled bulb, operated at 0.5 watts per candle and having a color temperature of approximately 3000° Absolute. An image of the filament was formed on the collimator slit of each instrument by means of a simple lens suitably placed to fill the prism, and the width of the collimator slit was kept constant at 0.3 mm. The ocular slits were removed from the two spectrometers, and the photometer so placed that its slit served in their stead. The image of one collimator slit in the minimally deviated wave-length was formed directly on the upper half of the photometer slit; and, by reflection at a right angle prism, a similar image of the other collimator slit was formed on the lower half of the photometer slit. A piece of colorless ground-glass was placed over this slit to give a field of uniform brightness. After passing through the slit of the photometer, the light passed through a collimating lens, a Wollaston polarizing prism, a bi-prism, an objective lens, a Nicol analyzer, and an eye-piece. The field, as observed through a circular opening 1 mm. in diameter and 1 cm. in front of the eye, was circular, subtending a solid visual angle of about 3°, and bisected horizontally. The upper half was filled with homogeneous light from one illuminator, and the lower half by homogeneous light from the other illuminator. The wave-lengths selected at the photometer slit were determined by proper rotation of the prisms of the spectrometers. The two halves of the photometer field were kept equal in brightness during the settings by proper rotation of the Nicol. The experimenter set the prism of one spectrometer so as to illuminate the standard, or upper, half of the field with light of a known wave-length, and the observer adjusted the drum of the other prism table with one hand, and the Nicol with the other hand, until the variable, or lower, half-field matched the standard in both hue and brightness. Except in the extreme blue and violet, in which there was a slight disproportionality in the amount of diffuse white light superposed on the compared spectra, there was no difficulty in setting so that the entire field appeared uniform. The field was of a high brightness between the extremes of the spectrum. It was not feasible, owing to the stringency of time, to keep the standard half-field constant in brightness for all wave-lengths. The results given by the several observers were obtained under identical visual conditions and the results are strictly intercomparable. The observing room was in semi-darkness.

The procedure was as follows: Beginning at the extreme red, 700 μμ, the two spectrometers were set so as to illuminate both halves of the field in the same wave-lengths. The observer was required to keep the two halves equal in brightness, and to turn the prism of the instrument illuminating the variable half-field until it appeared just noticeably different in hue from the standard. The reading was recorded by the experimenter; the difference was increased, and the observer required to turn the prism until the difference in hue just disappeared. Five paired settings were taken in this way, and the wave-length illuminating the standard half-field was changed to the mean of the ten readings to serve for the next standard. In this manner, the whole spectrum was worked through in short sittings, with frequent rest periods, for three observers, J. H., and two controls, E. S. (who also served in the luminosity experiments) and the writer. In the case of J. H., a second set of readings was taken, working from the violet, 410 μμ, to the red.

The results are presented graphically in Fig. 11, the long, folded chart. Along the base lines the 10 μμ divisions are indicated. Normal spectral limits are marked by the heavy lines (Fraunhofer, A and K) at either end. Since the Fraunhofer lines afford fixed points for reference, they are drawn in, with their wave-lengths and characteristic hues indicated. The small crosses give the initial starting points for each observer, and the arrows the direction followed. The short lines, perpendicular to and above the base, represent, in position, the discrimination intervals, each one marking the hue that is just perceptibly different from the preceding one under the conditions imposed. The height of these lines above the base shows the mean variation characterizing the average of the 'difference' and 'equality' settings; a height of 1.5 mm. being approximately equal to 1 $\mu\mu$ of variation as the chart appears after reduction. The initials at the left indicate the three observers.

Inspection of the curve reveals at once the vast difference between J. H. and the two control observers; for him hue discrimination practically does not exist. In his first record there are twelve recorded changes and in the second there are only six.[7] M. C. W. has under exactly similar conditions eighty-eight hue changes, and E. S. seventy-two. For J. H. there is no change from 700 $\mu\mu$ to 583 $\mu\mu$; "red" therefore is constant and unchanging in hue until well into the yellow. The few changes that then occur mass themselves for the most part within the next forty or fifty $\mu\mu$. At about 566 $\mu\mu$ a very narrow colorless or achromatic band appears, the limits for which have been very carefully determined. Passing on through the green which he calls "green" and into the blue which he also calls "green", changes are infrequent, until the violet, remarked as "green with some red in it," begins to appear, and continuing, color is finally lost, and "just light" remains. Could his spectrum be bent around into a circle, it would then show two achromatic bands; the one near 566 $\mu\mu$ already mentioned, and one between the violet and the red. The second record for J. H. is not qualitatively different from the first.

Hue changes for M. C. W. mass in two regions, the orange-yellow and blue-green. E. S. shows evident practice effects (supported by his verbal comments during the experiment) and his differences grow smaller rather gradually, but show a tendency to mass in the blue-green region also.

Neither M. C. W. nor E. S. attain the number of hue differences calculated by Koenig from Uhthoff's results, (5), namely 165. With practically the same apparatus that was used in this experiment, Dr. Johnson informs the writer that Nutting, in some unpublished experiments, obtained about 200 hue differences. Both J. H. and the controls however were quite without practice in this particular experiment.

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[7] This second record was made very hastily, just before J.H. had hurriedly to leave for the train, and it may have been influenced by that fact.

In connection with this experiment, J. H. made an observation which is interesting. It was noticed that he looked longer than usual at the color field with a certain setting of the spectrometers, (upper half of field 551.7 $\mu\mu$, lower half 554.0 $\mu\mu$ and somewhat darker). Asked what the difficulty was he replied: "It is beautiful and reminds me of an ocean sunset view at the equator. There is the sky all glowing red and the green ocean below. I have seen it that way many times." To the experimenter, who took a look at this seascape, there was a greenish yellow "sky" and a somewhat darker dirty yellow "ocean", and no straining of the imagination could make out of this a brilliant marine sunset comparable to those she had actually seen.

Matches between mixtures of two homogeneous lights and a single homogeneous light

The dichromat is usually able to match any spectral color by mixtures in suitable proportions of light from the extremes of the spectrum. A Hilger wave-length spectrometer of the fixed arm, constant deviation type, was set up as an illuminator so that one of the opal glass receiving surfaces of a photometer was illuminated by the wave-length suffering minimum deviation by the prism of the spectrometer and selected at its ocular slit. A high intensity monochromatic illuminator was used to fill the other half of the photometric field. This instrument was equipped with a train of two 60° dense flint glass prisms which were set for minimum deviation of $\lambda = 505\ \mu\mu$. The spectrum was formed on an acid-blackened brass plate containing three slit openings, the width and positions of which were independently variable. One of the slits was closed and the others placed so as to transmit a band at 672.6 $\mu\mu$ and another at 461.4 $\mu\mu$.[8] A projection lens was used to form an image in these two bands of the face of the first prism and the second receiving surface of the photometer.

The source used for both illuminators, were tungsten filaments in argon-filled bulbs, operated under steady current conditions and giving a color temperature of approximately 3000° Absolute.

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[8] The nearest fixed points to these hues are the red lithium at 670$\mu\mu$, and the blue helium at 471.3$\mu\mu$.

The field as observed was circular and subtended a solid visual angle of about 4°. Its mean brightness was high enough for comfortable reading, but was not measured. It was observed in dark surroundings through a circular opening 1 mm. in diameter and 1 cm. from the eye. The pattern was two half-circles each with a trapezoid. In all cases a match was obtained in which the pattern disappeared against the background.

The data secured in the mixing of spectral lights are not so extensive as had been planned, nor is the method of procedure so precise, for an unavoidable three-day absence from Cleveland made extensive work with the color mixing apparatus impossible. The original plan had been to proceed by taking definite proportions of the red and blue lights and find the monochromatic equivalents, working from 100% red + 0% blue to 0% red + 100% blue. What was actually done, however, was to take 10 $\mu\mu$ stops of monochromatic light along the spectrum, and determine empirically the proportions of mixed red and blue beams which would match for J. H. each monochromatic beam. An exact match was insisted upon, however; the pattern in the field (mixed light) was made to match the background (monochromatic) so that the former disappeared. The slit-width of the Hilger spectrometer illuminating the background was kept constant, so the luminosity curve is incorporated in the records. This means that, for the intense colors, wider, therefore more intense, red and blue beams had to be admitted.

An attempt was made to get a rough estimate of the relative stimulating values of the red and blue lights in terms of the same constant. The Hilger spectrometer was set by J. H. at the place where the background illuminated by it showed the least color, namely at 564.5 $\mu\mu$, slit-width 0.5 mm. A direct comparison luminosity match for this was found with red, 667.8 $\mu\mu$, to require a slit-width of 0.5 mm. The same for the blue, 460.3 $\mu\mu$, was 4.4 mm. Translating slit-width into wave-lengths, $\mu\mu$, this means that a beam of red light extending from 673.8 $\mu\mu$

to 667.8 μμ is approximately equal in stimulating value to a blue beam extending from 476.4 μμ to 460.3 μμ, since both, with unchanging light source, are apparently equal to the same unchanging monochromatic beam. Since hue discrimination practically does not exist for J. H., it may be assumed that the narrow beams here admitted were of one hue throughout.

TABLE IV

	Red			+ Blue		
Stand.	R. Jaw	L. Jaw	Range	R. Jaw	L. Jaw	Range
μμ	μμ	μμ	μμ	μμ	μμ	μμ
460	None			461.4	463.0	1.6
470	None			461.4	463.2	1.8
480	None			461.4	463.3	1.9
490	None			461.4	467.0	5.6
500	None			461.4	469.5	8.1
510	None			461.4	473.0	11.6
520	672.6	672.8	.2	461.4	473.5	12.1
530	672.6	672.9	.3	461.4	473.5	12.1
540	672.6	674.2	1.6	461.4	473.2	11.8
550	672.6	674.5	1.9	461.4	472.5	11.1
560	672.6	675.0	2.4	461.4	472.3	10.9
570	672.6	687.2	14.6	461.4	472.2	10.8
580	672.6	714.0?	41.4	None		
590	672.6	731.0?	58.4	None		
600	672.6	730.0?	57.4	None		
610	672.6	724.0?	51.4	None		
620	672.6	710.0?	37.4	None		
630	672.6	703.0	30.4	None		
640	672.6	702.0	29.4	None		
650	672.6	698.0	25.4	None		
660	672.6	685.0	12.4	None		

In Table IV the best one of three complete sets of records is given. The table is practically self explanatory. 'Range' refers to the width of the monochromatic beams in μμ admitted between the jaws of the slits allowing the selected beams to pass. The wave-lengths at each jaw of each slit are given merely for the sake of completeness. The interrogation marks indicate readings carried beyond the point of accurate calibration.

It is very desirable to plot the results of this experiment in a curve, but since the stimulating values of red and blue are so unlike, that cannot be done directly, nor do the records give for J. H. all the values necessary for making the calculations, and further it is probable that, although every effort was made to keep the physical conditions in the apparatus constant, many variables entered. An attempt was made to plot such a curve based upon certain calculated results; it is not presented on account of probable unreliability.

Von Kries (6) has emphasized the fact that a mixture of red (670.8 μμ) and yellow-green (550 μμ) will match for protanopes, deuteranopes and normal 'trichromats' a homogeneous yellow, although the three classes do not agree among themselves as to the proportions of red and green in the mixtures. Von Kries, however, does not keep the hue of his yellow constant, since in the table he gives, the wave-length varied from 569 μμ to 639 μμ. Although this test is not an especially critical one, the attempt was made with J. H. to match a homogeneous yellow (587.6 μμ yellow helium) with a mixture of red (667.8 μμ, third red helium) and green (501.6 μμ, second green helium). Intensity of the yellow was varied by changing the slit-width. The mixed light illuminated the pattern of the field, the monochromatic light the background. A direct comparison luminosity equivalent of yellow 587.6 μμ, slit-width 0.5, was found in the green, 501.6 μμ, slit-width 1.4 mm.; and in the red, 667.8 μμ, slit-width, 3.07 mm.

No attempt has been made to reduce the results to equal stimulating value. In Table V, the amount of each of the two colors in the mixture as empirically determined is stated in terms of the width of the beams in μμ's passed through the slits. The right jaws of the slits were fixed respectively at 667.8 μμ and 501.6 μμ.

TABLE V

Yellow 587.6μμ Slt-wdth. mm.	Green 501.6μμ Range μμ	+ Red 667.8μμ Range μμ
.8	1.5	71.2
.7	1.9	32.2
.6	1.6	17.2
.5	1.4	35.2
.4	1.6	37.2
.3	1.8	20.2
.2	1.5	10.2
.1	.7	4.2

The table shows that J. H. accepts relatively only a small amount of green in the mixture, and that this amount remains a fairly constant quantity as the luminosity of the yellow is successively reduced. The luminosity adjustment is made in the red. J. H. would rather have had no green in the mixture; he detected its presence and requested its withdrawal when the amount was increased. The yellow at 587.6 $\mu\mu$ is for him distinctly within the red, very near to the point which he selects as the "prettiest and brightest red in the spectrum", namely at about 600 $\mu\mu$, and might easily have been matched by different amounts of red alone. To the normal eye 587.6 $\mu\mu$ is practically an orange yellow.

The achromatic band

It was early discovered there was an apparently colorless band at about the place in the spectrum where the yellow begins faintly to appear for the normal eye. Its position was first rather definitely known when J. H. set an Hilger spectrometer to 564.5 $\mu\mu$ as showing the "least color". Later a slit with bilaterally movable jaws was put in the path of the spectrum at the place of greatest achromaticity, and the slit opened until the edges just marked the limits of this region. The average of five trials, fixed the limits at 568.2 $\mu\mu$ and 564.3 $\mu\mu$, indicating a band about 4 $\mu\mu$ wide, with the center at 566.2 $\mu\mu$.

Later on, a still more exact determination was made by adapting the hue discrimination apparatus. One-half of the field of the polarization photometer was illuminated with light from an Hilger instrument, the other half by a small tungsten automobile headlamp operated at 6 volts. Brightness equality was easily secured by rotating the Nicol prism. The Hilger drum which rotated its prism table was set first by the observer at a point where no color appeared when compared with the approximately white standard half-field, then the drum was turned toward the red until red just began to appear and the reading was taken by the experimenter. The drum was then rotated in the reverse direction until color ("green") began to come in from the opposite side. Five settings for each border limit were secured, which, when averaged, gave 568.38 $\mu\mu$ and 566.52 $\mu\mu$ as the limits. The range is 1.86 $\mu\mu$, and the center is located at 567.45 μμ. This is in very close agreement with the other determinations of the colorless band, and not far different from J. H.'s unaided setting of the Hilger at 564.5 μμ as the place of least color. From the band to the long end, the spectrum was called "red", and in the other direction it was "green" throughout, with no extensive shortening at either end. As has been noted previously however, were the spectrum bent in a circle, there would be another achromatic region between the violet and red.

Miscellaneous

Time did not permit definite experimental study of after-images and simultaneous contrast. Incidental observations were made from time to time and indicate that both these effects occur. In the case of contrast, when one half of the field was white, the other yellow, ("red"), some "green" was detected in the white.

White was repeatedly called white, and aside from obvious induction effects was never confused with a color.

The best, purest and brightest "red" he located at about 600 μμ; the best "green" at about 450 μμ, (M. C. W. best blue at 440 μμ). His "red" is thus really in the orange-yellow and his "green" in the blue.

What effect macular pigmentation has in this case is not known. His whole retina, including his macula, is rather densely pigmented, but it is not exceptional in this respect. Parsons says that the effect of macular pigmentation is to displace the achromatic band toward the long end, in this case, into the yellow. Color is probably not intense for J. H. in this region of the spectrum and macular absorption may be rather effective.

At various times, incidental tests were made to determine whether there was a marked difference between the two eyes. No noteworthy difference was found.

This study was begun, and for the most part pursued, without any conviction as to the type of color defect represented by J. H. It was sufficient to know that the case was unusual to stimulate the investigation. The study is not complete, but it is not certain that J. H. will be available for further work. Color theories are at the present time undergoing modification and new data are needed. The writer, then, presents these as the facts in hand, and submits the description without at this time attempting a diagnosis.

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BINAURAL BEATS

BY

G. W. STEWART

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Introduction

The subject of binaural beats has been one of much interest to the psychologist,[1] not only because the phenomena observed are difficult to explain with entire satisfaction, but also because the explanations involve what are evidently very important questions. The writer became interested in the physical aspects of binaural hearing through his theoretical and experimental studies[2] of the sound intensity and phase relations in the neighborhood of a rigid sphere. His experimental work upon the subject of binaural beats will be presented in appropriate detail in the Physical Review for 1917. The present article will give a very brief account of the results, both experimental and theoretical, with the expectation that those especially interested in this field will refer freely to the detailed reports in the Physical Review. Brevity will necessitate the preparation of this article for the most part as an abstract, and hence omissions of references to other investigations and of complete discussions of disputed points, will occur frequently.

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[1] An excellent review of the experiments with bilateral excitation is given by Rostosky, Beiträge zur Psychologie and Philosophie, I, 1905, pp. 173-273.

[2] G. W. Stewart, Physical Review, (1911), and N. S., (1913), (1914) and (1916).

Earlier Results

The chief phenomena observed when two tones differing in frequency are led one to each ear are as follows:[3]

(a) Beats occur whether the tones are presented to one ear or one to each ear. This was discovered by Dove,[4] observed subsequently by various experimenters and discovered independently by S. P. Thompson.[5] This phenomenon is observed by all, even by the partially deaf.

(b) With bilateral presentation of the tones, the minimum intensity observed in each beat does not (even with carefully adjusted equal intensities of the two sources) approximate zero. This is mentioned by S. P. Thompson[6] but doubtless was observed very much earlier by others.

(c) When the tones at the ears are alike in intensity and phase, there is a localization in the median plane, the position in this plane varying with the observer and presumably with the apparatus arrangement. Purkyné[7] was the first to record this localization, which has been shown through numerous experiments of other observers, to be a usual accompaniment of binaural perception.

(d) With opposition in phase and equality in intensity, the sound is localized according to S. P. Thompson[8] at the back of the head. To several observers, with apparatus of a form different than that of Thompson's the localization is in the median plane. Doubtless the position in the median plane is influenced by the method of observation.

(e) The sound is localized on the side of the fork leading in phase when the phase difference is approximately 90°. Thus with phase difference the sound wanders from the median plane at 0° to one side at 90°, to the median plane at 180°, to the other side at 270° and again to the median plane at 360°. Perhaps S. P. Thompson[9] first observed the wandering from ear to ear but the periodic displacement of the localization was first most clearly described by Paul Rostosky.[10] Later workers, who were not aware of Rostosky's results, observed this lateral displacement. Lord Rayleigh,[11] experimenting with forks, recognized the lateral effect and its relation to phase difference, and later[12] confirmed these observations with experiments conducted by the use of telephones. L. T. More and H. S. Fry[13] made preliminary experiments which were followed by those of L. T. More.[14] His results showed unmistakably the lateral displacement. More used an apparatus similar to that earlier adopted by C. S. Myers and H. A. Wilson.[15] A single source, branched pipes to the ears and an arrangement whereby the lengths of the pipes could be altered in opposite senses, were used. The experiments of Myers and Wilson also gave full confirmation of the lateral effects. Bowlker's[16] experiments do not seem to furnish reliable evidence. Unfortunately, the workers just mentioned seem not to have been aware of the splendid experiments of Rostosky published in 1902.[17]

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[3] Unless otherwise stated, the difference of freqnency is assumed to be small.

[4] Loc. cit.

[5] S. P. Thompson, Phil. Mag. 5, IV, 1877, p. 274.

[6] Loc. cit.

[7] Purkyné Prager Vierteljahrsschrift, Bd. 67, p. 91, 1860.

[8] S. P. Thompson, Phil. Mag. 5, IV, 1877, p. 274, and Phil, Mag. 5, VI, 1878 p. 383.

(f) There is a limit to the frequency of the tone with which the effect just described (e), can be obtained. L. T. More[18] states that a fork of 512 d. v. was near to his limit of accuracy in the judgment by phase differences, that with 1024 d. v. his judgment became untrustworthy and that with 3000 d. v. he had no sense whatever of direction. Lord Rayleigh[19] gives the limiting frequency of his right and left sensations at 768 d. v. C. S. Myers and H. A. Wilson[20] state in general terms that with very high frequencies the lateral effects cannot be obtained.

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[9] S. P. Thompson, Phil. Mag. 5, XII, 1881, p. 351.

[10] P. Rostosky, Philosophische Studien, 19, 1902, p. 557.

[11] Lord Rayleigh, Phil. Mag. XIII, 1907, p. 214.

[12] Lord Rayleigh, Phil. Mag. XIII, 1907, pp. 316-319.

[13] L. T. More and H. S. Fry, Phil. Mag. XIII, 1907, p. 452.

[14] L. T. More, Phil. Mag. XVIII, 1909, p. 308.

[15] C. S. Myers and H. A. Wilson, Proc. Roy. Soc. LXXX, 1908, p. 260.

[16] T. J. Bowlker, Phil. Mag. (6) XV, 1908, p. 318.

[17] Loc. cit.

[18] Loc. cit.

(g) In addition to the maximum at 0° phase difference, there are also two additional maxima occurring one before and the other after opposition in phase, but distinctly perceptible only when the beats are less frequent than one in two to five seconds. These additional maxima were first studied by Paul Rostosky[21] in 1902, but in the succeeding literature no reference is made to his important contribution. Thus the subsequent discovery of these secondary maxima by the writer was an independent one.

Observations with Mr. F. C. Bruene

The tones were obtained with two tuning forks, the sounds being led to the ears by binaurals inserted[22] in the opening of the external meatus. Phase relations were determined by the Lissajou's figures made by a beam of light reflected from two mirrors, one attached to each fork.

The following results were obtained with the assistance of Mr. F. C. Bruene, a graduate student in the Department of Philosophy and Psychology.

(1) The beats (i. e., maximum at 0° and minimum at 180° phase differences) with the tones of two forks, one applied to each ear, were heard distinctly. Indeed, of twenty-three inexperienced observers listening for three periods of five minutes each, seventeen noticed the beats distinctly enough to report them. All experienced observers can hear them and record them with very satisfactory accuracy.

(2) There existed a distinct wandering of the localization; in front at 0° difference of phase, on the side of the fork with the higher frequency leading in phase from 0° to 180°, and on

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[19] Lord Rayleigh, Phil. Mag. XIII, 1907, p. 214.

[20] Loc. cit.

[21] Loc. cit.

[22] See section VII in which there is a discussion of the use of binaurals closing the external meatus.

the side of the slower fork with the higher frequency leading in phase from 180° to 360°, the changes of position being continuous, from front to rear, (or within the head), and from rear to front. This wandering when first recognized might be described as occurring in a circular path. A more accurate description occurs in what follows.

(3) This rotation of the localization just described was quickly and distinctly observed by some hearers; on the other hand all observers did not recognize it, even with an hour or more practice. Eleven of the twenty-three uninstructed and inexperienced observers reported their observation of this "rotation" after fifteen minutes' trial (three trials of five minutes each). Six of these eleven noticed the effect within the first five minutes, and three in the second.

(4) All of the eleven just mentioned, with the possible exception of one or two, noticed that the localization was much more distinct in the half cycle in which the lead of the faster fork varies from —90° to +90°. With experienced observers, the effect is very noticeable.

(5) Extended experiments with four experienced observers showed that the most accurate judgment as to phase difference, made by the localization, occurred when that difference is 0°.

(6) With the experienced observers the change in the localization at 0° phase difference by the production of a very marked inequality in intensities, is slight. The rotation of the localization was modified by a slight circular shift in the direction of the side of the greater excitation. The effect upon the localization at the sides became very marked, that on the side of the greater intensity becoming more prominent and that on the other almost vanishing.

(7) With observers of experience, but who had not yet recognized the secondary maxima,[23] the maximum intensity seemed to occur at 0° phase difference when the beat-period was less than perhaps two seconds. With a greater and gradually increasing period there arose an uncertainty until, with a period

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[23] See pp. 35, 37 and 41 of this article and (9) below.

of perhaps five seconds, the judgment of maximum intensity shifted to a phase difference noticeably less than 180°, or approximately to the first occurring secondary maximum.

(8) The rotation of localization with experienced observers occurred as follows: At 0° phase difference the sound was localized as in front and distant, i. e., external to the head. The localization then described in a horizontal plane a path which appeared to be somewhat circular, but in which the apparent distance contracted until the path entered the ear leading in phase. Then at about 180° phase difference the localization passed quickly through the head, into the other ear and from thence around to the front along a path symmetrical to the one just described.

(9) When an experienced observer gave his attention to apparent intensity rather than to localization, there appeared three fairly distinct maxima. One occurred at 0° difference of phase, one at $180° - \delta$ and one at $180° + \delta$, δ being less than 45°. The earlier of the additional maxima at $180° - \delta$ phase difference coincided with the localization in the ear near the higher frequency, and the later one with the localization in the other ear. With a 128 d. v. fork the secondary maxima seemed clearly discernible only if the beat-period exceeded a value of approximately two seconds. The value given is only approximate as the variation in the perception of the secondary maxima is continuous with the changing of the beat-frequency. The significant fact is that the 0° maximum was always present, whereas the secondary ones required a beat-period exceeding at least a second in order to become clearly evident.

(10) The localization in the ears as described seemed to depend upon the perception of the secondary maxima. If they were absent, as at high beat-frequency, the localization seemed confined to the region near the front. In other words the localization in approximately one-half the cycle seemed to be due to the secondary maxima or the causes producing them.

Observations upon the Secondary Maxima

Again the binaurals inserted[24] in the ears were used. The observations were made with the assistance of Dr. Harold Stiles of Iowa State College. As already stated, the secondary maxima are those occurring just before and after the 180° difference in phase, or at phase differences of $180°-\delta$ and $180°+\delta$. The results were obtained by extended observations upon pairs of forks of the following frequencies: 42, 63, 128, 256, 361, and 469 d. v. The length of the beat-period and time between the secondary maxima were measured. From these values $\frac{\delta}{\pi}$ was computed. The results are shown in Tables I, II and III. The number given in parentheses after the values of 2δ in Table I and after the values of $\frac{\delta}{\pi}$ in Tables II and III, is the actual number of observations involved in the value given of 2δ or $\frac{\delta}{\pi}$. The conclusions are as follows:

(11) The difficulty of determining the exact moment of the occurrence of a maximum renders the measurement of δ inaccurate. Observations were, however, made at various times of day and the average results do seem to warrant the two conclusions that follow.

(12) For a given pair of forks δ is independent of the frequency of the beats when this frequency is varied from one to three times. This is shown especially in Table I.

(13) δ does vary with the fork frequency, and this variation is not linear, varying less rapidly than the frequency. This is shown by the averaged values taken from all the tables.

A Theory of Binaural Beats

The phenomena already mentioned are complex and hence we will divide the theoretical discussion into three parts, namely, the primary maxima, the secondary maxima and the localization.

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[24] See footnote 22.

TABLE I

Fork of 128 d. v.

Date	Period of beats	2δ in seconds	$\frac{\delta}{\pi}$	$\frac{\delta}{\pi}$
Aug. 3	27.8		.20	
	12.3	2.60(7)		.21
	12.2	3.50(7)		.29
	13.1	2.75(8)		.21
Aug. 10	35.7	7.9 (4)	.22	
	35.5	7.2 (6)	.20	
	36.0	10.3 (9)	.29	
	13.7	2.95(12)		.22
	14.0	3.6 (11)		.26
Aug. 11	35.2	7.9 (4)	.22	
	13.3	2.68(10)		.20
	13.5	3.1 (6)		.23
	Mean		.23	.23

TABLE II

Forks of 42, 63, and 128 d. v.

Fork of 42 d. v.			Fork of 128 d. v.		
Date	Beat Period	$\frac{\delta}{\pi}$	Date	Beat Period	$\frac{\delta}{\pi}$
Aug. 11	20.4	.19(10)	June 27	23.2	.25(2)
	20.2	.20(8)		10.1	.29(8)
Aug. 12	22.6	.18(10)	June 29	23.9	.24(3)
	23.7	.16(8)		31.0	.22(3)
	22.6	.18(9)		16.0	.27(4)
	24.5	.15(11)	July 2	35.8	.22(4)
	21.6	.17(13)	July 3	27.8	.20(6)
	21.5	.18(10)		12.3	.21(7)
				12.2	.29(7)
	Mean	.17		13.1	.21(8)
			July 10	36.0	.29(9)
				35.5	.20(6)
				35.7	.22(9)
				13.7	.22(12)
Fork of 63 d. v.				13.7	.25(10)
Aug. 3	10.1	.20(11)		14.0	.26(11)
	10.7	.20(13)		13.6	.20(7)
	10.8	.18(11)	July 11	13.3	.20(10)
Aug. 5	10.2	.18(·4)		13.5	.23(9)
	19.5	.16(6)		35.2	.22(4)
	19.0	.14(4)			
				Mean	.23
	Weighted Mean	.18			

The Primary Maxima.—If we assume that there is sound conduction across the head by paths not entirely aerial, and that the organ of hearing detects actual intensity, or an effect which depends upon the square of the amplitude of vibration, and if we further assume that there is a blending which results

TABLE III

Forks of 256, 361, and 469 d. v.

Fork of 256 d. v.

Date	Beat Period	$\frac{\delta}{\pi}$
July 13	13.2	.26(9)
" "	12.2	.29(9)
" 14	43.8	.26(4)
" "	27.4	.27(8)
" "	23.4	.21(8)
" "	12.0	.28(11)
" "	10.5	.26(9)
" "	9.25	.27(9)
	Mean	.26

Fork of 361 d. v.

Date	Beat Period	$\frac{\delta}{\pi}$
June 26	15.9	.28(9)
" "	8.2	.29(10)
July 20	17.6	.28(6)
" "	22.3	.26(7)
" "	17.1	.25(8)
" 27	10.7	.27(9)
" "	10.2	.24(15)
" "	11.7	.30(5)
" "	9.1	.28(9)
" "	12.5	.22(7)
Aug. 1	12.7	.30(6)
	Mean	.27

Fork of 469 d. v.

Aug. 5	4.2	.32(1)
" "	4.0	.37(2)
" "	6.6	.27(4)
" "	5.6	.35(2)
" "	5.0	.38(2)
" "	5.0	.26(3)
" "	7.0	.27(3)
	Mean	.32

in the effects at the two ears appearing as one, we obtain the result that the total sensation must vary with the following expression:

$$2(\alpha^2+\beta^2)+4\alpha\,\beta\cos\epsilon\cos\lambda$$

where α and β are constants, ϵ is the phase by which the faster fork leads the slower, and λ is the difference between the phases introduced in the two paths, one from the source to the nearer ear and the other from the source to the farther ear. Thus ϵ is the only variable in the expression, and hence the total sensation must pass through a maximum and a minimum (not zero), the former corresponding to $\epsilon = 0°$ and the latter to $\epsilon = 180°$. According to the experimental results just presented, this theory agrees with the fact that the maximum and minimum do occur at the phase difference specified, the fact that the minimum is not zero; and the fact that phase differences for maxima and minima are independent of either fork-frequency or beat-frequency.

The Secondary Maxima.—The only theory proposed for the explanation of the secondary maxima has naturally been that of the only previous observer, P. Rostosky.[25] He contended that they were caused by the variation in intensity-ratio, but, unfortunately, in the interpretation of his equations, he made an error[26] which when corrected makes his theory contradict experimental facts.

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[25] P. Rostosky, Philosophie Studien, 1902, 19, p. 557.

In order to explain not only the secondary maxima, but various other related phenomena, we are compelled to make several assumptions in addition to the ones just stated in the preceding discussion. An inspection of the experimental results will convince that the secondary maxima must have an origin quite independent of the primary maxima. The assumption will therefore be that the organ of hearing is, from a physical point of view, duplex. A pair of "A" instruments is responsible for the primary maxima and a pair of "B" instruments is responsible for the secondary maxima. We accept, then, the existence of the B instruments and in addition make the following assumptions: that the blending with the B is not as perfect as with A instruments, that with the former there is introduced an additional change of phase of 180° in the wave transmitted across the skull and that the B instrument is excited by the skull rather than by the air-membrana tympani route. We find by a theoretical investigation that the intensity in the ear nearer to the faster fork reaches a maximum at $180° - \lambda$ and in the further ear at $180° + \lambda$, where λ is as previously defined. Thus we have explained the existence of the secondary maxima as the recognition of the individual intensities at each B instrument, and λ is identified as the δ observed experimentally. Thus the result stated under (g) is explained. If the B instruments are excited by the skull, which is comparatively massive, a certain length of time would be required to set up any vibratory motion in these B instruments. This is in accord with the experimental fact, as expressed in (9), that the secondary maxima are not in evidence unless the primary beat-period exceeds one or two seconds. The fact that δ is independent of beat-frequency as stated in (12) above, is due to the fact that the retardation λ (in the theory) depends only upon the frequency of vibration and the conducting paths and not upon the rate at which the phase differences of the sources are changing, or upon the beat-frequency.

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[26] See article on "Theory of Binaural Beats," by G. W. Stewart, in the Physical Review for 1917.

The fact that δ is dependent upon the fork-frequency, as stated in (13) above, is in agreement with the theory, for the time retardation along any path is constant and the phase retardation is strictly proportional to the frequency. Furthermore it can be shown[27] that when there are numerous paths between two points, the resulting phase retardation cannot in general be a linear function of the frequency. Thus our theory is in harmony, qualitatively, with the measurements of δ.

The failure to recognize the secondary maxima at the very beginning of one's experience with binaural beats, (7), can be explained by our assumption that the blending of the sensations produced by the B instruments is only partial.

The Localization. Our theory is in accord with the experimental fact that during a portion of the beat-cycle, *i. e.,* in the region $\epsilon = 0°$, the localization is external, and in the portion near the region $\epsilon = 180°$, the localization is internal. For in the former case the excitation (of the A instruments) is by the usual means, air-drum-skin-etc., and in the latter case, the excitation (of the B instruments) is through the skull which, as we know by direct experiments, (8), gives an internal localization.

In order to bring our theory into agreement with all the experiments on localization described above, we must make two additional assumptions, namely, that the localization with the A instruments depends chiefly upon phase difference and that with the B instruments chiefly upon intensities. The former assumption will perhaps not be regarded by all as a reasonable[28] one, but the latter involves a principle generally accepted.

At $\epsilon = 0°$, the resulting phase difference at the pair of A instruments is zero and hence the localization is in the median plane. The fork near to an ear will furnish the greater portion of the amplitude and thus the variation of phase at each A instrument can be assumed to be chiefly determined by the phase of the nearer fork. Thus the localization in the region, $\epsilon = 0°$ follows, approximately, the variation of ϵ. And we note that the movement of localization, experimentally, is in accord with this result, for it seems, as in (8), to proceed at a uniform angular velocity.

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[27] See article on "Theory of Binaural Beats," Physical Review, 1917.

[28] J. Peterson, loc. cit., assumes that the perception of phase differences is cortical in origin.

In the region $\epsilon = 180°$, the excitation of the B instruments is the more prominent and hence controls the sensation experienced. That the localization at or in an ear occurs both at $180° - \delta$ and $180° + \delta$, where δ is less than, say, 45° is in accord with theory in that λ (or δ) must be small because of the high velocity of conduction in the bones of the skull. As yet the quantitative agreement, if we accept possible values of the velocity of sound in the bones, is not very good. But the possible conducting paths are numerous and do not actually terminate on the opposite side of the head from the source, and hence a quantitative agreement should not be anticipated.

The fact that δ is less than 45° makes the angular velocity of localization apparently much more rapid, as in (8), in the region $\epsilon = 180°$.

The continuation of the localization in the region $\epsilon = 0°$ and the absence of the localization in one ear when the source on that side is made of much less intensity, as in (10), is in accord with the above theory, for in the first case the difference of phase is only slightly dependent upon the equality of intensity, and in the second the maximum of intensity would be blotted out by the partial blending.

The difference in distinctness of the localization, described in (4), and the most accurate judgment of phase difference at $\epsilon = 0°$ are experimental facts which are also in accord with our theory.

These explanations bring our theory of binaural beats into apparent harmony with the experimental facts concerning localization recorded above in (c), (d), (2), (4), (5), (6), (8) and (10).

The fact that the rotation of localization is not found with all observers is doubtless to be explained upon the basis that the localization is a "second-order effect" as compared with intensity observations. The theory as here presented does not explain why the rotation of localization in the region, $\epsilon = 0°$, is similar with all frequencies, the same difference in phase meaning the same displacement. This phenomenon may have a wholly physical basis, but that is not certain. Full consideration has not yet been given to this point.

Anatomical Considerations

The query arises, does the structure of the ear permit of the assumptions as made? It would seem that no serious objection arises if we assume the instrument A to be the organs of Corti in the ductus cochlearis, and the instrument B to be the analogous organs in the saccule or the utricle. These organs in the cochlea and the saccule and utricle, have a common origin. Herrick[29] states that some physiologists have thought that cochlear and vestibular nerve systems are not wholly distinct and that the sense organs in the saccule may also function as a sound perceptor. This uncertainty concerning the function of the organs in the utricle and saccule on the part of physiologists does not serve as an objection to our theory. Indeed, the fact that the complex phenomena herein described can be accounted for by the assumption of the existence of the B instruments ought to assist in deciding this uncertainty. The fact that there is a great difference in the central connections of the cochlear and vestibular nerves is in harmony with our contention that the instruments B give sensations which do not completely blend and which do not produce external localization.

But are the vestibular and cochlear organs mechanically different? Obviously they are, for the latter are placed upon a membrane, and are apparently excited by the motions of the fluid in the scala media, and the motions of the basilar membrane and the tectorial membrane. The vestibular organs are located at the points where the membranous labyrinth is fastened to the skull itself. Moreover, the movement of the vestibular fluid must be very small for the vestibular canals are closed.

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[29] G. J. Herrick, Introduction to Neurology, pp. 201-202.

Thus there would seem to be a mechanical difference which corresponds admirably with our assumption that instrument A is excited via the vibration of the membrana tympani and that instrument B is excited by the skull. The only change in our assumption induced by the structure of the ear would be the possible insertion of the word "chiefly" after each word "excited" occurring in the preceding sentence.

A paper of importance has just come to the writer's notice. D. Richards[80] reports upon experiments with a guinea pig in which there were removed (1) both cochleae, (2) both cochleae, and one vestibule and (3) both labyrinths. His conclusion is that sound stimuli may be regarded as adequate stimuli for the vestibular apparatus, but that no conclusion can be drawn as to any sensation produced in this way. This contribution is entirely favorable to the theory presented in this paper.

Restatement of Theory and Agreement with Experiment

By the assumption of two physical instruments A and B on each side, having a difference in mechanical arrangement, a difference in the method of excitation, a difference in the blending of the sensations of the A pair and B pair of instruments and an independence of sensations produced by the two pairs and the additional assumptions that instruments A, the usual instruments of hearing, can perceive phase differences, and that in the skull conduction to the B instruments there is an additional phase change of 180°, we have a theory that explains fairly satisfactorily the presence of the primary maxima, the secondary maxima, the appreciable length of beat-period requisite for the appearance of the latter, the localization in the entire beat-cycle, the difference in the nature of the localization and in the quality of the sound in the two halves of the beat-cycle, the rapid movement of localization between the secondary maxima, the variation of the separation of the secondary maxima with the fork-frequency, and its independence of beat-frequency, the difference in the effects of unequal intensities upon the localization in the two halves of the beat-cycle, and finally the simultaneous disappearance of the secondary maxima and the localization in the region of 180° phase-difference.

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[80] D. Richards, Zeitsch. f. Biol. 1916, 66, pp. 579-609.

Our theory does not lead us to identify the B instruments, but merely to suggest the possibility of these instruments being located in the utricule and saccule. Anatomical and physiological considerations give evidence in favor of the suggestions.

Inasmuch as all of the experiments recited in the foregoing pages were performed with binaurals that were inserted into the ears, the query naturally arises as to whether or not the phenomena involved are dependent upon this insertion of binaurals. From a physical point of view the partial closing of the external meatus would not be likely to change the characteristics of the phenomena. But the actual experimental evidence of the truth of the similarity of results with inserted binaurals and binaurals free from the head is obtained by a comparison of the results of Rostosky,[31] who used the latter type of binaurals, and of the writer who tried both in all experiments excepting the quantitative measurement of δ. The results of these two investigators are in entire agreement. Hence it is believed that the theory is equally applicable to open-ear-binaurals.

The theory is, of course, incomplete, but it has herein proved to be very successful and hence promising. There are no conspicuous phenomena connected with binaural beats that are not in accord with the theory, but there are minor points that should receive further consideration. For example, S. P. Thompson[32] has found binaural beats occurring when the tones used have frequencies of almost two to one.

In the theory presented it is assumed that the sensation produced depends upon the intensity or upon the square of the amplitude of vibration. But this assumption is open to question. Might not the sensation vary with the absolute value of the amplitude? Might not an assumption be made that will permit of both the primary and secondary maxima without a necessity for the hypothesis of a second organ of hearing? The first question has been answered by a theoretical investigation assuming the variation of the sensation to depend upon the absolute value of the amplitude. This investigation shows that the same maxima and minima occur as with the assumption of sensation as a function of intensity. But the second question remains unanswered. The writer merely opines that no assumption as to the variation of the sensation will lead to the possibility of the primary and secondary maxima without the additional assumption of two hearing instruments.

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[31] Loc. cit.

[32] S. P. Thompson, Phil. mag. (5), IV, 1877, p. 274.

I wish to express my thanks to Mr. F. C. Bruene and to Dr. Harold Stiles for their assistance in different portions of the experimental work herein described.

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CORRELATION OF FACTORS IN MUSICAL TALENT AND TRAINING

BY

Carl E. Seashore and George H. Mount

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INTRODUCTION

We have here undertaken to assemble and interpret, for the technical reader, some of the data available in this laboratory on the interrelations of various factors in musical talent.

For the last fifteen years or more, a mass of data bearing on this subject has been accumulating until it is now unquestionably the largest collection of its kind. Most of these data have been presented, or will be treated in the discussion of individual problems by different investigators; but the presence of this material suggests the possibility of a mass-survey of the various kinds of records in this series for the purpose of finding out something about the inter-relationships of the factors under consideration.

All the records considered have been taken upon University students in the elementary course in psychology, all in or above the sophomore year. The plan has been to take the entire class in order to eliminate the error of selection. The tests have been made under very favorable conditions, either as class tests under accurate control or as individual tests in the special measuring rooms of the psychological laboratory.

Some of the tests have been made for more than ten successive years on from one hundred to three or four hundred different students. Instead of attempting to use all of the data available, we have selected certain groups, or cross sections, which are representative, namely the records taken in the years '07, '09, '11, and '16. This selection excludes a few relevant tests which were taken only in other years.

Dr. Mount originally undertook this task and completed his doctor's thesis on this subject in 1910, having devēloped the material given here for the years, 1907 and 1909. The fact that the same investigation was continued by his immediate followers led to the postponement of publication and, during the time that elapsed, certain parts of the tests particularly the section on the distribution of musical talents, have been superceded by more intensive studies along some of these lines, notably, the measurements on pitch by Smith (16), and on singing by Miles (6).

In Dr. Mount's original treatment of this subject, a new method of expressing correlations was developed consisting essentially of a characteristic figure, (K), representing the distribution of records into quartiles or octiles, a figure somewhat analagous to the "r" in the Pearson coefficient. Since this method has not been followed up in later researches, it was thought best to use the coefficient R of the Spearman foot-rule in the present article in order that these data might be more nearly comparable to those contained in the data worked over by his followers.

It would be poor economy for the reader to have Dr. Mount's original interpretation of the correlations presented separately from those of his followers. Therefore, with his courteous consent, the correlation data which he had worked out are here used as a part of the larger body of the same kind of material, and his original thesis will not be published for the reasons given; namely, that other parts of his thesis are superceded by later work now published, that the reading public will welcome the whole report as one unit, and that his original interpretations, in so far as they are substantiated, are embodied in the present interpretation of the material as a whole.

The group of data for the year, 1911, was collected by Dr. Rollin M. Stewart, who put much valuable time and energy into the evaluation of the questionnaire returns and the ranking of students on the questionnaire. He did not find time to work out the correlations and write up the subject himself, and therefore turned over the material to the writer.

The materials for 1916 were assembled from the various investigations by Mrs. Esther Allen Gaw to whom the writer is also indebted for continued help in the work in her capacity as research assistant in the field of this investigation. The first named of the authors has written this entire article on the material mentioned and takes all responsibility for the interpretations herein presented. He wishes to express his hearty appreciation of the coöperation of many whose names are not mentioned. He, and all the other workers in this field, are under special obligation to Dr. Mabel Clare Williams for her valuable guidance and supervision of these tests.

The terse account of the various tests which follows can be excused only on the ground that in most cases reference is given to published accounts which should be read in detail if the procedure is to be fully understood or repeated.

It would not seem necessary to go into details as to the conditions of the experiments, which would in themselves fill a large volume, because our only interest in the present issue is in the correlation problem; it is sufficient to know that the same procedure was followed for all the members of a given group or year for which the figures have been compared.

Likewise one might go into great detail in the discussion of the merits and demerits of various methods of computing and representing correlations, means of attenuating, weighting, etc., but that we must also forego and proceed by the simplest method. It should be said that the demand for considering attenuations of correlations and other adjustments was reduced to a minimum by the fact that the measurements were made under good laboratory control, and that the number of cases on which each correlation was based is relatively large. In '07 the minimum was about 190, in '09 about 200, in '11 about 225, and in '16 about 225, but each year a much larger number of cases was taken for some of the correlations.

As stated above the Spearman foot-rule was used for '07 and '09 because much of the material could be best handled by the method of ranking. This was also used for the questionnaire returns in '11. Otherwise, in '11 and '16 the coefficient "r" of the Pearson product-moments method was used. This diversity of standard is unfortunate and must be kept in mind in reading.

The Spearman method, larger formula, gives the higher correlation as is shown by comparing the "R" and the "r" in two actual items.

'07 R, .40, p.e. .04 is equivalent to r, .59, p.e. .03

'09 R, .49, p.e. .03 is equivalent to r, .70, p.e. .02

The general formula by which one may be converted into the other in a very rough estimate is either $r = \sin\ (\frac{\pi}{2}\ R)$ which is Spearman's empirical formula, or $r = 2 \cos\ \frac{\pi}{3}\ (1\text{-}R)\text{-}1$ which is Pearson's theoretical formula to give the r of the product-moments method from Spearman's R.

SOURCES OF MATERIAL

1. *Pitch discrimination.*—This measurement was made according to the standard conditions laid down by the writer in the article on the standardization of measurement of pitch discrimination (12). Briefly, the standard was 435 v.d. and ten differential forks ranged from ½ v.d. approximately in a geometric ratio of the second order up to 30 v.d. The tones were sounded through Helmholtz resonators. The "heterogeneous" method, described at length in the above reference (12), was followed, and it was found possible to make from 170 to 200 trials in the one hour.

These tests were made on groups of students from 100 to 200. In '09 this test was followed by individual tests, using the method of constant stimuli at the threshold found in the group test. The records for '09 were accordingly labeled "group tests" and "individual tests" respectively, and the plain "P.D." in Table II, without qualification, denotes the mean between the two.

In '09 a practice series of three periods was also given. The observers were divided into three divisions on the basis of records made in the first test. Division A included all whose threshold was below 4, Division B those whose threshold was between 4 and 10, and Division C those whose threshold was above 10. The three divisions were tested simultaneously but in different rooms by different experimenters. Division A was given fifty trials upon each of the increments 5, 3, 2, and 1 respectively. Division C was tested in the same way upon increments 12, 8, 5, and 3, respectively, and Division C was tested upon increments

30, 17, 13, and 12 respectively. The threshold was determined by applying the Fullerton-Cattell formula (3) with reference to the cases in which the records were between 65 and 85 per cent.; records on other intervals were discarded except when new intervals fell within the limits indicated.

Measurements in 1907 were made by the writer and Dr. Williams, in 1909 by Dr. Mount, in 1911 by Dr. Smith (16) and in 1916 by Mrs. Gaw.

2. *Consonance.*—All the measurements on consonance were made by the method described in Dr. Malmberg's article on the perception of consonance in this volume (5). Briefly, the procedure was this: Malmberg had ranged all possible two-clangs in the octave from c′ to c″, in the order of consonance-dissonance, for the piano. This order was used as a norm and the measurement was made by the method of paired comparison, each two-clang being compared with every other as sounded on a well tuned piano. Errors were then checked by the norm named above, and these errors were weighted according to the magnitude of displacement from the true order according to the norm. Thus if c′d′ was said to be better than c′c″ a demerit of 11 was given. If c′d′ was said to be better than c′g′ a demerit of 9 was given, etc., there being a scale of demerits from 11 to 1 according to the magnitude of the error. The record was kept in terms of the per cent. of weighted credits for right judgments above the one-half which would be right by chance. For full understanding of this method it is necessary to read Malmberg's original statement.

A critical feature of this test is the definition of consonance. It was pointed out to the class that consonance may be regarded from two points of view, that of feeling and that of knowing, and that our point of view was the latter, and consonance was accordingly defined by the following placard:

1. Blending: a seeming to agree, to belong together, to be relatively pure.
2. Smoothness: relative freedom from beats.
3. Purity: thinness of tone.

This was read and interpreted to mean, "When the two tones of a two-clang tend to blend or fuse and produce a relatively smooth and pure resultant, they are said to be consonant."

The '11 records were taken by Dr. Malmberg and the '16 records by Mrs. Gaw. Attention should be called to the fact that this test has since then been modified as reported by Mrs. Gaw in this volume (4).

3. *Intensity discrimination.*—The measurement of discrimination for intensity of sound was made in the light-, sound-, and jar-proof room (7) of the psychological laboratory with the audiometer (10). The interrupted current reduced to 1.8 volts from a 100 v.d. tuning fork was sent through the audiometer. This produced a tone which was clearly audible. The strength of this tone was kept constant.

The '11 tests were made by Mr. W. S. Smiley and the '16 by Miss Marie M. Agnew.

4. *Hearing ability.*—Hearing ability was also measured by means of the audiometer (10) in the light-, sound-, and jar-proof room (7).

The audiometer was used, as above, but without the tuning fork, and the current was reduced to the standard strength according to the audiometer galvanometer. Ten determinations were made of the upper limit and ten of the lower limit of the threshold and the mean between the averages of these two was taken as the characteristic measure of hearing ability.

All known subjective and objective sources of error were under reasonable control. The record was taken for the better ear according to the judgment of the observer.

These tests were made by Mr. W. S. Smiley in '09 and by Miss Marie M. Agnew in '16.

5. *Time-sense.*—The measure of time-sense was the least perceptible difference in the length of two empty intervals marked off by three clicks in a telephone receiver. In 1911 the timing was done by the synchronous motor as described by Ross (9). An adjustable contact lever was attached to the shaft of the motor in such a way that when the motor revolved at the rate of one revolution per second, this contact could be shifted from the standard point, for one of the intervals, making it shorter than one second by a given differential step. The steps employed were 1, 2, 3, 5, 8, 12, and 17 hundredths of a second.

In 1916 the same measurement was made by means of the

Dunlap pendulum (2) which is a very large and accurately built seconds pendulum. In this case the middle click, *i.e.,* the click at the end of the first interval, was placed earlier or later than the standard according to the same differential steps as before. This resulted in the lengthening of one interval and the shortening of the other whereas in the '11 test with the synchronous motor one interval was kept constant and the other shortened. This difference was, however, of no consequence for the present purpose. The pendulum was substituted for the synchronous motor in order to develop a norm for the pendulum which can be used in simple and readily transportable form.

The '11 tests were made by Mr. Ross (9) and the '16 by Miss Pauline Peters.

6. *Motor ability.*—The test of motor ability was the customary procedure of tapping with a telegraph key adjusted with a spring requiring about 50 grams of pressure and moving through a distance of one millimeter. The record was made with a multiple recorder tracing on ticker tape by the method described for the psychergograph (9) by the writer. This multiple recorder is a sort of a "universal apparatus" for the laboratory, convenient for all sorts of prolonged time and signal records. The time line was traced from a 25 v.d. tuning fork. When indelible leads are used and the tape is run under a moist sponge, the moisture of the paper develops the light tracing into a clear and permanent record.

This and the next three tests were made by Miss Pauline Peters in '16.

7. *Free rhythm.*—Free rhythm was measured in the terms of the average error in the free marking of time at the suggested rate of approximately one beat per second. The record was made on the multiple recorder as above.

We have followed custom in calling this rhythm. It is really not a rhythm test but a test of motor-time, or time-action. The same is true of "regulated rhythm" also.

This and the next test on regulated rhythm were made by Miss Margaret Cummings in '11.

8. *Regulated rhythm.*—Regulated rhythm was measured in terms of the average error in keeping time with a click produced

at intervals of one second in a telephone receiver operated through a seconds pendulum. The original object of this experiment was to study personal equations but for the present purpose only the average error was counted.

9. *Rhythmic judgment.*—"Rhythmic judgment" is something of a misnomer. It consisted in marking time with the telegraph key through the multiple recorder (13) as before, the instructions being to mark time, giving in each measure two short and one long intervals. The record was made in terms of the deviation of the long interval from the sum of the two short.

10. *Singing the keynote.*—All measurements on the singing of pitch were made by means of the tonoscope (14). Singing the keynote was measured in terms of the average error in reproducing the standard tone sounded by a tuning fork before a resonator. In most cases the standard was 256 v.d., the women being allowed to sing this pitch and the men an octave lower. This method was followed because the men preferred to take the key from a 256 v.d. fork rather than from a 128 v.d. fork, as a result of association with notes on musical instruments. This measurement was not made in and by itself but was taken from the singing of the keynote in singing intervals, scales or minimal change; but for each year it was the same for the entire group, which is all that is necessary for us to ascertain for the present purpose. It will be observed that the note sung was in the middle register of voice both for men and women.

All the measurements of singing were made by Dr. David Allen Anderson (1) in '09, by Dr. Walter R. Miles (6) in '11, and by Esther Allen Gaw in '16.

11. *Singing the interval.*—In '09 the test consisted of the singing of the three intervals, the major third, the fifth, and the octave after sounding the keynote in each trial, the measure being in terms of the average error, as calculated from the standard as sung rather than as sounded by the keynote.

In '16 this test consisted of the singing of the first two phrases of America, record being made of the average error in the sounding of the notes which occur for the words, *my, 'tis, sweet, of, of, sing.*

12. *Singing the scale.*—Each observer was required to sing

the natural scale within a middle register of the voice, in just intonation.

13. *Voluntary control of pitch.*—This is the measurement of the least producible difference, or the minimal change, in sharp or flat as described by Miles (6).

14. *Singing.*—This ranking is based on the mean between the singing of the key and the minimal change as described above, a single measure being used for the two.

15. *Auditory imagery.*—In '16 the test as outlined in the writer's Manual of Elementary Experiments in Psychology (11, Ch. IX), was supplemented by a one-hour experiment devoted entirely to auditory and motor imagery in which the stimuli were a broken melody, printed words, spoken words, and sounds to be imaginally imitated. The records used for the purpose of correlation were the mean between the Manual test and the record for this special test on auditory imagery. The method of ranking the images described in the Manual was followed and the records were kept in terms of the percentage of points possible.

The '11 tests were made by Dr. D. J. Macdonald, and the '16 tests of this and motor imagery by Miss Marie Agnew.

16. *Motor imagery.*—Motor imagery was measured according to the directions given in the Manual of Elementary Experiments in Psychology (11, Ch. IX), section on motor imagery. This was supplemented by a test on the imaging of a series of tones. The mean between these two records was used as the final grade.

In this test, although the observer was warned to distinguish between motor sensations and motor imagery, it is safe to assume that this was not done successfully; and it is probable that much of what the untrained observer did record as motor imagery may have involved motor sensations.

17. *Tonal memory.*—Tonal memory was measured in terms of the memory span for notes on the piano according to the method developed by Sodergren (17). Briefly, a series of notes in the middle octave of the piano was sounded. Immediately thereafter the same series, with but one change, was sounded and the observer was required to tell which of the notes was different in the second stimulus group. The spans of two notes, three notes,

four notes, five notes, and six notes were used under controlled conditions. The test lasted one hour and the record was made in terms of the percentage of right cases in all the trials. From these records an evaluation was worked out showing to what a given percentage of right cases in the total number of trials would be equivalent in terms of 75 per cent. of right cases on a given span.

This test was made in '16 by Mrs. Gaw.

18. *Supplementary information.*—All persons examined were requested to fill out the following questionnaire:

Name.. Age.......
Date................................ Hour...... Class......

Please give as specific and detailed information as possible in regard to your:

I. MUSICAL TRAINING
  1. In public schools
  2. Private vocal lessons (when, where, how long, etc.)
  3. Private instrumental lessons (when, where, how long, etc.)

II. MUSICAL ENVIRONMENT
  1. Instruments in your home, and their use
  2. Musical encouragement at home (trained voices in family)
  3. Opportunities for hearing music of any sort (specific)

III. MUSICAL EXPRESSION
  1. Favorite selections you can sing (by ear? by note?)
  2. Favorite selections you can play (by ear? by note? instruments?)
  3. Singing or playing in public (parts, occasions, etc.)

IV. ENJOYMENT OF MUSIC (WHAT ACTUALLY APPEALS TO YOU)
  1. Vocal (solo, quartette, chorus, opera, popular songs, classics, religious, secular)
  2. Instrumental (solo, symphony, band, etc.)
  3. Characteristic effects of music (mental, physical)

All were charged to make the information as full, specific, and concrete as possible. Often a questionnaire was returned for more accurate information. In many cases this information was supplemented by personal interviews on significant points. Notes were also taken in the various tests placing on record facts which could be used in this section.

All the ratings in the section were made without knowledge of the objective records. The rating is arbitrary, but was, nevertheless, done with extreme care and patience in the effort to sift the facts. Various devices were used for the evaluation of answers in the different years. The record for musical training being made in terms of hours of instruction, public school training had to be reduced to this unit. Vocal and instrumental lessons were treated with different value.

The most elaborate evaluation is that worked out by Dr. Rollin M. Stewart for '11, but it is not necessary to go into details about this procedure because the same method was followed for all in the entire group for a given year and the title of each item is perhaps sufficiently descriptive.

Mount differentiated instrumental training from vocal training for the purpose of tracing the relationship of each of these two factors separately. The first item on the questionnaire, musical training, is, therefore, based on a composite record of instrumental and vocal training. The same principle of division was followed for "musical expression."

TABLES OF CORRELATION

The records for the four years selected are presented in Tables I to IV. Attention is called to the fact that the first two and a part of the third are in terms of the Spearman R; and that the third, in part, and the fourth wholly are in terms of the Pearson r. Absence of sign indicates a positive correlation.

TABLE I—*Series of 1907*

	P.D.	M.Tr.	I.Tr.	V.Tr.	M.Env.	M.Ex.	I.Ex.	V.Ex.
Musical Training	.31 .04							
Instrum. Training	.27 .04	.94 .00						
Vocal Training	.20 .05	.34 .04	.23 .05					
Musical Env.	.12 .05	.26 .05	.25 .05	.15 .05				
Musical Exp.	.38 .04	.51 .03	.42 .03	.25 .05	.35 .04			
Instrum. Exp.	.28 .04	.65 .02	.68 .02	.12 .05	.38 .04	.77 .02		
Vocal Exp.	.32 .04	.14 .05	.06 .05	.24 .05	.21 .05	.61 .03	.23 .05	
Musical Enj.	.27 .04	.22 .05	.23 .05	—.04 .05	.03 .05	.12 .05	.13 .05	.08 .05

The upper figure in each pair is R of the Spearman foot-rule formula; the lower is the p. e. of R.

TABLE II—*Series of 1909*

	P.D.	P.D. Av.	P.D. Ind.	S.K.	S.I.	S.Sc.	S.	M.T.	I.T.	V.T.	M.Env.	M.Ex.	I.E.	V.E.
P.D. Av.	.64 .02													
P. D. Ind.	.68 .02	.68 .02												
Singing Keynote	.14 .05	.32 .04	.21 .04											
Singing Interval	.15 .05	.28 .04	.19 .05	.45 .04										
Singing Scale	.24 .04	.34 .04	.25 .04	.42 .04	.47 .03									
Singing	.26 .04	.37 .04	.29 .04	.76 .02	.75 .02	.78 .01								
Musical Training	.16 .04	.19 .04	.10 .05	.14 .05	.23 .04	.18 .05	.18 .05							
Instr. Training	.15 .05	.16 .05	.11 .05	.11 .05	.39 .04	.14 .05	.18 .05	.96 .00						
Vocal Training	.18 .04	.31 .04	.20 .04	.26 .04	.15 .05	.07 .05	.17 .05	.28 .04	.13 .05					
Musical Env.	.17 .04	.28 .04	.17 .04	.24 .04	.18 .05	.16 .05	.22 .04	.30 .04	.28 .04	.12 .05				
Musical Exp.	.31 .04	.42 .04	.36 .04	.23 .04	.24 .04	.31 .04	.32 .04	.48 .03	.47 .03	.26 .04	.30 .04			
Instr. Exp.	.22 .04	.29 .04	.29 .04	.15 .05	.21 .04	.25 .04	.32 .04	.60 .03	.66 .02	.14 .05	.34 .04	.79 .01		
Vocal Exp.	.22 .04	.31 .05	.27 .04	.24 .04	.28 .04	.34 .04	.34 .04	.07 .05	.00 .05	.54 .03	.11 .05	.56 .03	.18 .04	
Musical Enj.	.13 .05	.12 .05	.07 .05	.04 .05	.05 .05	.06 .05	.01 .05	.03 .05	.05 .05	.19 .04	.15 .05	.16 .04	.20 .04	.19 .04

The upper figure in each pair is R of the Spearman foot-rule formula; the lower is the p. e. of R.

TABLE III—*Series of 1911*

	P.D.	C.D.	I.D.	F.R.	R.R.	S.	A.I.	M.I.	M.T.	M.Env.
Cons. Discr.	.33 .05									
Intensity Discr.	.13 .05	—.03 .05								
Free Rhythm	.27 .05	.03 .05	—.05 .05							
Regulated Rhythm	.01 .05	—.11 .05	.18 .05	.04 .05						
Singing (Ave.)	.12 .05	.04 .05	.14 .05	.26 .05	.07 .05					
Auditory Imagery	.29 .04	.14 .05	.05 .05	.22 .05	.17 .05	.07 .05				
Motor Imagery	.02 .05	—.02 .05	—.05 .05	.06 .05	.11 .05	—.07 .05	.52 .04			
Musical Training	.21 .03	.14 .03	.03 .03	.06 .03	.03 .03	.09 .03	.21 .03	.04 .03		
Musical Env.	.13 .03	.03 .03	.01 .03	.09 .03	.07 .03	.05 .03	.13 .03	—.03 .03	.28 .03	
Musical Enj.	.06 .03	—.02 .03	.01 .03	.04 .03	—.01 .03	.06 .03	.11 .03	.11 .03	.10 .03	.13 .03

The upper figure is the r of the Pearson product-moments method; except in the last three lines, for musical training, musical environment, and musical enjoyment, which represent the Spearman R; the lower is its p. e.

TABLE IV—*Series of 1916*

	P.D.	C.D.	I.D.	H.A.	T.S.	M.A.	F.R.	R.R.	R.J.	S.K.	S.I.	V.C.	A.I.	M.I.
Cons. Discr.	.21 .04													
Intensity Discr.	.09 .04	.11 .04												
Hearing Ability	.12 .04	.01 .04	.16 .04											
Time Sense	.17 .04	.07 .05	.15 .04	.03 .04										
Motor Ability	—.02 .05	.03 .04	.01 .04	.24 .04	.01 .04									
Free Rhythm	.18 .04	.03 .04	.17 .04	.005 .04	.08 .04	.09 .04								
Regulated Rhythm	.21 .04	.01 .04	.05 .04	.09 .04	—.01 .04	.12 .04	.14 .04							
Rhythmic Judgment	.22 .04	.30 .04	.001 .04	—.06 .04	—.03 .04	.03 .04	.15 .03	.00 .00						
Singing Keynote	.21 .04	.30 .04	.28 .04	.11 .04	.001 .04	.10 .04	.01 .04	.13 .04	—.04 .04					
Singing Interval	.22 .04	.21 .04	.27 .04	.32 .04	.10 .04	.21 .04	.07 .04	.23 .04	—.05 .04	.61 .03				
Voluntary Control	.38 .04	.01 .04	.10 .04	.001 .04	.01 .04	—.05 .04	.07 .04	.11 .04	.08 .04	.55 .03	.32 .04			
Auditory Imagery	.29 .04	.06 .04	.04 .04	.03 .04	.19 .04	.06 .04	—.01 .04	.001 .04	.08 .04	.24 .04	.40 .04	.29 .04		
Motor Imagery	.07 .04	.01 .04	.01 .04	.22 .04	.13 .04	.10 .04	.07 .04	.08 .04	.07 .04	.19 .04	.21 .04	.08 .04	.42 .04	
Tonal Memory	.52 .03	.23 .04	.26 .04	—.01 .04	.17 .03	.10 .04	.09 .04	.05 .04	.22 .04	.32 .04	.30 .04	.50 .03	.40 .04	.16 .04

The upper figure is the r of the Pearson product-moments method; the lower is its p. e.

COMMENT ON THE CORRELATIONS

Consonance and pitch discrimination: '11, r, .33, p.e., .05; '16, r, .21, p.e., .04.

Although the perception of consonance depends upon pitch discrimination it is not closely limited by that, for it is safe to say that eighty-five per cent. of all persons have sufficiently good pitch discrimination to hear consonance well enough to secure a record above the average in so far as it depends upon pitch discrimination alone. In other words, pitch discrimination is not the only determining factor in consonance; blending, fusion, smoothness, and purity may be perceived to some extent apart from perception of pitch, as such.

Intensity discrimination and pitch discrimination: '11, r, .13, p.e., .05; '16, r, .09, p.e., .04.

These two factors have but little in common. What there is may perhaps be thought of in general as a tendency toward ear-mindedness. Physiologically the two factors are quite independent in normal hearing.

Hearing ability and pitch discrimination: '16, r, .12, p.e., .04.

It is conceivable that defective hearing-ability (acuity) may be due to anatomical and physiological conditions which involve the organ of Corti and would therefore result in defective pitch discrimination; but most of the causes of defective hearing are due to disturbances elsewhere in the ear. The correlation may be due in part to the pathological condition in the ear, and in part to factors in psychological disposition, such as ear-mindedness and power of application.

Time-sense and pitch discrimination: '16, r, .17, p.e., .04.

Pitch and time are rightly regarded as independent variables in hearing. The variability in pitch is due mainly to structural or functional differences in the ear, whereas variability in the perception of time is due to motor and central factors. It may be that a part of the correlation is due to the capacity for improving the cognitive threshold with practice, in cases of relatively low ear-mindedness; *i.e.,* some, who are dull and are not ear-minded, may have gotten low records in both tests because of their general inability to respond to the test.

Motor ability and pitch discrimination: '16, r, -.02, p.e., .05. This tallies well with what we know of the independence of these factors; and the absence of correlation speaks well for the elemental character of these two tests. That is, each is so simple that it does not involve acquired skill or general intelligence on a large scale. The two tests were equally fair to the bright and the dull, the quick and the slow.

Free rhythm and pitch discrimination: '11, r, .27, p.e., .05; '16, r, .18, p.e., .04.

Free rhythm involves all the elements of time-sense plus musical feeling and a certain agility in action; it is the motor aspect of which time-sense is the sensory or central. The tests in free rhythm for '11 were really more reliable than those for '16. The correlation, it is reasonable to suppose, may be traced to the feeling for, or interest in, sounds which is favored by a keen ear for pitch; that is, hearing differences of pitch tends to result in expression of pitch, and all musical expression tends to become rhythmical.

Regulated rhythm and pitch discrimination: '11, r, .01, p.e., .05; '16, r, .21, p.e., .04.

Probably a mean between these two records would represent the facts in the long run. Regulated rhythm is time-sense plus precision of action. The feeling element of free rhythm is not so conspicuous. Regulated rhythm represents a higher cognitive or central affair, with temporal precision in action, and is quite independent of sensory limitations.

Rhythmic judgment and pitch discrimination: '16, r, .22, p.e., .04.

Rhythmic judgment does not involve the feeling element and here again the correlation may be laid to that factor, as in free rhythm.

Singing the keynote and pitch discrimination: '09, R, .14, p.e., .05; also R, .32, p.e., .04; '16, r, .24, p.e., .04.

Miles (6, p. 61) found a correlation between these two factors as follows; for eighty-four men, the correlation between pitch discrimination and the average error in singing the keynote was r, .04, p.e., .07; and for pitch discrimination and the constant error in singing the keynote it was r, .08, p.e., .07. For one hundred and four women he found, for pitch discrimination and the average error, r, .27, p.e., .06; and, for pitch discrimination and the constant error, r, .11, p.e., .06. These facts of the comparatively low correlation between the hearing of pitch and singing of pitch may be somewhat surprising, but the singing test is far from elemental; and, as in consonance. the average pitch hearing is good enough for excellent pitch singing. Singing, which is motor control, often does not reach the hearing limit and in so far as it does not, there should be no correlation.

On this question of relation between hearing of pitch and singing of pitch in learning to sing, an investigation has been completed by Mr. Carl J. Knock and will be published in the next volume of these *Studies.*

Singing intervals and pitch discrimination: '09, R, .15, p.e., .05; also R, .28, p.e., .04; and R, .19, p.e., .05; '16, r, .32, p.e., .04.

Miles (6, p. 61) found, for forty-eight men, a correlation of R, .33, p.e., .08 for pitch discrimination and average error in singing the interval, and for pitch dicrimination and the constant error in singing the interval, r, .15, p.e., .07. For one hundred and four women the corresponding records were r, .51, p.e., .05, and R, -.07, p.e., .06 respectively. These strong correlations between pitch discrimination and the average error in singing the interval cannot be attributed wholly to the presence of pitch discrimination in the hearing of intervals. The common element, that is, a general sense of pitch must be taken into account. Intervals must be learned; those who have a good ear for pitch are the ones who practice and develop an interest in intervals. The correlation was, therefore, due largely to the fact that those who have a good sense of pitch take time to practice on the intervals.

The records by Miles on correlation of pitch with constant error in singing involve different factors. The constant error is due to certain motives for illusion which become fixed and habitual; by some motive for constant error, a person may have a concept of the interval which is persistently flat or sharp by a certain amount. The constant error is in part an error of concept and in part an error of memory for that concept. This accounts for the low correlation between pitch discrimination and constant error in the interval found by Miles.

Singing the scale and pitch discrimination: '09, R, .24, p.e., .04; also R, .34, p.e., .04; and R .25 p.e., .04.

What has been said about the average error in singing of intervals applies equally here.

Voluntary control and pitch discrimination: '16, r, .38, p.e, .04.

Of all types of singing this is the most closely dependent upon pitch discrimination because the problem is to sing the least producible difference. All things taken into account, the correlation here given seems to be characteristic of this relationship. It must be remembered that, without practice, one is not likely to learn the motor control that will actually produce as small a difference as can be heard.

Singing and pitch discrimination: '09, R, .26, p.e., .04; also R, .37, p.e., .04; also R .29, p.e., .04; '11, r, .12, p.e., .05.

These composite records are not of much value for correlation, because different principles are involved in each of the component elements.

Auditory imagery and pitch discrimination: '11, r, .29, p.e., .04; '16, r, .29, p.e., .04.

Where there is a common element which relates pitch discrimination to other sensory and motor processes in singing, it probably comes most frequently through the channel of auditory imagery. The correlations here shown are good. One may question which of the two factors is the basic. Does auditory imagery depend upon pitch discrimination in so far as pitch is concerned, or does the opposite relationship obtain? Auditory imagery, which we ordinarily designate as ear-mindedness is, as it were, a general vehicle for other factors. Without entering into the dispute as to the rôle of images in successive comparisons of tones, we may assert that the image is present and probably favors discrimination. The correlation here shown seems to represent fairly the judgment of most observers in regard to this relationship according to introspections. Those who have low auditory imagery tend to have poor and uncertain pitch discrimination.

Motor imagery and pitch discrimination: '11, r, .02, p.e., .05; '16, r, .07, p.e., .04.

From the fact that a keen sense of pitch would naturally develop motor responses and images of such responses to sound, one might have expected a larger correlation here. Its absence is conspicuous; it is undoubtedly due in part to the difficulty untrained observers find in identifying motor images.

Tonal memory and pitch discrimination: '16, r, .52, p.e., .03.

Memory is notably a faculty that responds to training. The accurate hearing of tones leads to the development of a natural memory for tones; conversely, indifferent hearing is even more certain to suppress attention to tones. Indirectly also, those who had formed the habit of hearing pitch were favored in the detection of the changed note which was often only a half-tone.

Musical training and pitch discrimination: '07, R, .31, p.e., .04; '09, R, .16, p.e., .04; '11, R, .21, p.e., .03.

a. Instrumental: '07, R, .27, p.e., .04; '09, R, .15, p.e., .05.

b. Vocal: '07, R, .20, p.e., .05; '09, R, .18, p.e., .04.

This item is perhaps the most significant. It raises two questions: Do those who have good sense of pitch seek musical training? And, does musical training improve pitch discrimination?

Observation of the many thousand cases we have, bearing on this point, leads us to the conclusion that those who have a good sense of pitch tend to like music, but only a comparatively small per cent. of these receive training. This fact in itself is perhaps adequate to account for the correlation here shown. The second question has been answered in the negative by Smith (16) and others, in so far as it refers to actual psycho-physic capacity.

It was thought that the relationship might be significantly different for instrumental and vocal music, the theory being that singing, like violin playing, offered special training in the precision of pitch hearing; but the figures do not warrant any such distinction. The explanation of this probably lies in the fact that very little, if any, voice training is directed toward precision in pitch because the ear of both pupil and teacher is lenient and there is no objective aid employed as a check.

Musical environment and pitch discrimination: '07, R, .12. p.e., .05; '09, R, .17, p.e., .04; '11, R, .13, p.e., .03.

Environment is a part of education. It is also a mark of hereditary relationship. The relatively small correlation here shown for these two important factors supports the view that training in the hearing of pitch is a universal affair of normal hearing—like the perception of distance in vision. It reaches its normal development early in childhood through the ordinary use of sounds. If we may assume that the sense of pitch is an heritable character, that may account practically for the correlation here found.

Musical expression and pitch discrimination: '07, R, .38, p.e., .04; '09, R, .31, p.e., .04.

a. Instrumental: '07, R, .28, p.e., .04; '09, R, .22, p.e., .04.

b. Vocal: '07, R, .32, p.e., .04; '09, R, .22, p.e., .04.

These correlations involve essentially the same principles as in musical training. This concerns only the amount of musical activity. It is evident that the next point of interest should be a study of correlations with quality of achievement in musical expression.

The separation of vocal and instrumental expression seems to throw no light on the situation.

Musical enjoyment and pitch discrimination: '07, R, .27, p.e., .04; '09, R, .13, p.e., .05; '11, R, .06, p.e., .03.

One noteworthy peculiarity of special talent is that its absence is often not noted. One who has poor sense of pitch does not hear his own faulty pitch or the errors of others; he is satisfied and enjoys the many other aspects of music, apparently satisfied that music is to him what it is to others.

Average pitch discrimination in the practice series and the usual pitch discrimination, i.e., the first group test: R, '09, .64, p.e., .02.

Individual test of pitch discrimination by the method of con-

stant stimuli and the usual pitch discrimination of the first group test: R, '09, .68, p.e., .02.

Average of the pitch discrimination in the practice series and the individual test: R, '09, .68, p.e., .02.

In judging these relations it should be born in mind that a single group test cannot be counted on to establish the approximate physiological threshold in much more than half of the cases. Smith says: "Success in making a true measurement on an inexperienced observer in a single sitting varies with the knowledge, keenness, and care of the observer and the many objectively favorable or unfavorable conditions of the test as well as the experimenter; but, everything taken into account, it is safe to say that when an individual test is made under favorable conditions the approximate physiological threshold may be reached in a single sitting of less than an hour in more than half of the cases of adults or children who are bright and are old enough to understand the test. Even in group tests by the heterogeneous method one may reach in an hour the approximate physiological threshold of nearly half of the observers who are old enough and bright enough to observe." (16, p. 100).

It is, therefore, to be expected that the practice series and the individual test should both lead to readjustment. For this reason the correlation here shown is satisfactory as evidence of the stability of a single rough test. The fact that the correlation between the first group test and the individual test (presumably more accurate) is no greater than between the individual test and the average for the practice series, also speaks well for the first group test.

Intensity discrimination and consonance: '11, r, .03, p.e., .05; '16, r, .11, p.e., .04.

These two tests involve, to some extent, the same general power of critical attention to sound. It is difficult to explain the small correlation in '11.

Hearing ability and consonance: '16, r, .01, p.e., .04.

Time-sense and consonance: '16, r, '07, p.e., .05.

In these two cases it is rather remarkable that no significant correlation comes out here on account of the common element of musical appreciation. The absence of correlation speaks for the elemental character of the tests.

Motor ability and consonance: '16, r, .03, p.e., .04.

No relation.

Free rhythm and consonance: '11, .03, p.e., .05; '16, r, -.03, p.e., .04.

Regulated rhythm and consonance: '11, r, -.11, p.e., .05; '16, r, .01, p.e., .04.

Comment for these two here same as for time-sense.

Rhythmic judgment and consonance: '16, r, .30, p.e., .04.

Singing the keynote and consonance: '16, r, .30, p.e., .04.

Singing intervals and consonance: '16, r, .21, p.e., .04

In the last three items the element of selection undoubtedly enters because those who have good consonance are likely to develop rhythmic judgment and accuracy in singing. It is difficult to identify other factors.

Voluntary control of pitch and consonance: '16, r, .01, p.e., .04.

Singing and consonance: '11, r, .04, p.e., .05.

The element of selection does not enter because these tests involve activities which never enter into music in this form, although it is the best test of pitch control. Voluntary control rests primarily upon pitch discrimination and motor ability. The absence of correlation with general singing ability in '11 is due to the fact that this record is based partly upon voluntary control.

Auditory imagery and consonance: '11, r, .14, p.e., 05; '16, r, .06, p.e., .04.

It seems strange that there is no higher correlation between these two factors, because the appreciation of consonance seems to rest largely upon that sort of mastery of details in tones which is ordinarily thought of as associated with the vivid representation of sounds.

Motor imagery and consonace: '11, r, -.02, p.e., .05; '16, r, .01, p.e., .04.

No correlation.

Tonal memory and consonance: '16, r, .23, p.e., .04.

This undoubted correlation is probably due in part to the common element of familiarity with tones and interest in them.

Musical training and consonance: '11, R, .14, p.e., .03.

It is a comment on our processes of selection for musical training that there is so small a correlation between the sense of consonance and the opportunities for musical training.

Musical enjoyment and consonance: '11, R, -.02, p.e., .03.

No correlation; which indicates that the sense of consonance, like pitch discrimination, is an inborn capacity manifesting itself in, and developing through, the interest in, and dependence upon, the perception of qualitative differences in the world of sound which constitutes a part of the natural and ever present environment from early childhood, quite apart from its specialized form in music.

Musical enjoyment and consonance: '11, R, -.02, p.e., .03.

No correlation. This is a great puzzle. The evaluation of musical enjoyment is of course rather loose, while the measure of consonance is quantitatively quite accurate. It would be interesting to know to what extent this absence of correlation is due to inability of non-musical people to recognize the fact that they do not enjoy music as musical people do.

Hearing ability and intensity discrimination: '16, r, .16, p.e., 04.

Although these two activities seem similar they are not closely related, because hearing ability varies with the physical condition of the ear whereas, so far as we know, variation in the intensity discrimination for sound is largely due to psychological factors. It is however conceivable that some physical defects of the ear may be of such a nature as to affect both to the extent indicated by this correlation.

Time-sense and intensity discrimination: '16, r, .15, p.e., .04.

The common element here would seem to be the general capacity for sensory observation, if such there be.

Motor ability and intensity discrimination: '16, r, .01, p.e., .04.

Free rhythm and intensity discrimination: '11, r, -.05, p.e., .05; '16, r, .17, p.e., .04.

Regulated rhythm and intensity discrimination: '11, r, .18 p.e., .05; '16, r, .05, p.e., .04.

These three tests are alike in stressing precision.

Rhythmic judgment and intensity discrimination: '16, r, .00, p.e., .04.

Absence of correlation may be due to imperfection in the test of the judgment.

Singing the keynote and intensity discrimination: '16, r, .28, p.e., .04.

Singing intervals and intensity discrimination: '16, r, .27, p.e., .04.

Voluntary control and intensity discrimination: '16, r, .10, p.e., .04.

Singing and intensity discrimination: '11, r, .14, p.e., .05.

These are large correlations in the absence of dependence of one factor upon the other. The demand for auditory precision is the common element.

Auditory imagery and intensity discrimination: '11, r, .05, p.e., .05; '16, r, .04, p.e., .04.

Motor imagery and intensity discrimination: '11, r, -.05, p.e., .05; '16, r, .01, p.e., .04.

No correlation.

Tonal memory and intensity discrimination: '16, r, .26, p.e., .04.

From one point of view, intensity discrimination and memory span belong to the same type of process, differing only in the length of the retention.

Musical training and intensity discrimination: '11, R, .03, p.e., .03.

No correlation.

Musical environment and intensity discrimination: '11, R, .01, p.e., .03.

Musical enjoyment and intensity discrimination: '11, R, .01, p.e., .03.

Time sense and hearing ability: '16, r, .03, p.e., .04.

No significant correlation in these three cases.

Motor ability and hearing ability: '16, r, .24, p.e., .04.

This is a large correlation in view of the absence of specific common elements.

Free rhythm and hearing ability: '16, r, .01, p.e., .04.

Regulated rhythm and hearing ability: '16, r, .09, p.e., .04.

Rhythmic judgment and hearing ability: '16, r, -.06, p.e., .04.

No significant correlation in these two cases.

Singing keynote and hearing ability: '16, r, -.11, p.e., .04.

Singing intervals and hearing ability: '16, r, .32, p.e., .04.

Large correlation in the latter in view of the observed common elements.

Voluntary control and hearing abiltiy: '16, r, .00, p.e., .04.

Auditory imagery and hearing ability: '16, r, .03, p.e., .04.

No significant correlation in these two cases.

Motor imagery and hearing ability: '16, r, .22, p.e., .04.

No reason known for this correlation.

Tonal memory and hearing ability: '16, r, -.01, p.e., .04.

Motor ability and time-sense: '16, r, .01, p.e., .04.

No correlation.

Free rhythm and time-sense: '16, r, .08, p.e., .04.

Regulated rhythm and time-sense: '16, r, -.01, p.e., 04.

Rhythmic judgment and time-sense: '16, r, -.03, p.e., .04.

It is difficult to account for relative absence of correlation in these three cases.

Singing the keynote and time-sense: '16, r, .00, p.e., .04.

Singing intervals and time-sense: '16, r, .10, p.e., .04.

Voluntary control and time-sense: '16, r, .01, p.e., .04.

No noteworthy correlation.

Auditory imagery and time-sense: '16, r, .19, p.e., .04.

Motor imagery and time-sense: '16, r, .13, p.e., .04.

These correlations are significant because in time-sense both auditory imagery and motor imagery are conspicuous, according to introspections.

Tonal memory and time-sense: '16, r, .17, p.e., .03.

Tonal memory and time-sense are both memory tests.

Free rhythm and motor ability: '16, r, .09, p.e., .04.

Regulated rhythm and motor ability: '16, r, .12, p.e., .04.

The common element is general motor control.

Rhythmic judgment and motor ability: '16, r, .03, p.e., .04.

No correlation.

Singing the keynote and motor ability: '16, r, .10, p.e., .04.

Singing the keynote is, from one point of view, a motor control and it is safe to hazard the assumption that, to the extent that singing in key is at its maximum efficiency, the correlation between the motor ability and this capacity would increase. This point however remains to be established by further experiment; it represents a very important problem in vocational guidance as well as in pure psychology, or pedagogy.

Singing intervals and motor ability: '16, r, .21, p.e., .04.

The larger correlation here may indicate that the smaller correlation just noted for singing the keynote is exceptionally small. Theoretically the correlation for singing the keynote should be larger than this because it presents more of a problem of motor control.

Voluntary control and motor ability: '16, r, -.05, p.e., .04.

No correlation. Here again we are puzzled by the absence of correlation because precision in the control of the voice would seem to be related to motor ability in so far as it is independent of the hearing of pitch which is, of course, the largest determining factor.

Auditory imagery and motor ability: '16, r, .06, p.e., .04.

No marked correlation.

Motor imagery and motor ability: '16, r, .10, p.e., .04.

This correlation may be significant in that it may point to the existence of a general tendency which we may call motor-mindedness.

Tonal memory and motor ability: '16, r, .10, p.e., .04.

The explanation of this tendency towards correlation is uncertain.

Regulated rhythm and free rhythm: '11, r, .04, p.e., .05; '16, r, .14, p.e., .04.

It is difficult to account for the absence of correlation in '11, since these two factors involve several elements in common.

Rhythmic judgment and free rhythm: '16, r, .15, p.e., .03.

The relations are similar to those of regulated rhythm.

Singing the keynote and free rhythm: '16, r, .01, p.e., .04.

Singing intervals and free rhythm: '16, r, .07, p.e., .04.

Voluntary control and free rhythm: '16, r, .07, p.e., .04.

No significant correlation.

Singing and free rhythm: '11, r, .26, p.e., .05.

Correlation exceptionally large.

Auditory imagery and free rhythm: '11, r, .22, p.e., .05; '16, r, .01, p.e., .04.

It would seem probable that the correlation for '11 is more indicative of the true relation than the absence of correlation for '16.

Motor imagery and free rhythm: '11, r, .06, p.e., .05; '16, r, .07, p.e., .04.

Absence of correlation here seems strange.

Tonal memory and free rhythm: '16, r, .09, p.e., .04.

Musical environment and free rhythm: '11, R, .09, p.e., .03.

Correlation comparatively small.

Rhythmic judgment and regulated rhythm: '16, r, .00, p.e., .00.

Further refinements of these tests must be made.

Singing the keynote and regulated rhythm: '16, r, .13, p.e., .04.

Singing intervals and regulated rhythm: '16, r, .23, p.e., .04.

Voluntary control and regulated rhythm: '16, r, .11, p.e., .04.

Singing and regulated rhythm: '11, r, .07, p.e., .05.

The common element in these cases seems to be essentially the attitude of precision in action.

Auditory imagery and regulated rhythm: '11, r, .17, p.e., .05; '16, r, .00, p.e., .04.

Motor imagery and regulated rhythm: '11, r, .11, p.e., .05; '16, r, .08, p.e., .04.

The correlation for '11 in auditory imagery would seem to be a truer representative than the absence of correlation in '16; yet the low correlation in both auditory and motor imagery has great significance in the interpretation of the rôle of imagery in action.

Tonal memory and regulated rhythm: '16, r, .05, p.e., .04.

No significant correlation. From one point of view regulated rhythm involves memory; from another, it may be viewed as limited to the sensory span as distinguished from memory span.

Singing and regulated rhythm: '11, r, .07, p.e., .05.

Musical training and regulated rhythm: '11, R, .03, p.e., .03.

Musical environment and regulated rhythm: '11, R, .07, p.e., .03.

Musical enjoyment and regulated rhythm: '11, R, -.01, p.e., .03.

The absence of correlation in the last three cases raises a question about the significance of mechanically accurate appreciation of rhythm for musical enjoyment.

Singing the keynote and rhythmic judgment: '16, r, -.04, p.e., .04.

Singing intervals and rhythmic judgment: '16, r, -.05, p.e., .04.

Voluntary control and rhythmic judgment: '16, r, .08, p.e., .04.

No significant correlation.

Auditory imagery and rhythmic judgment: '16, r, .08, p.e., .04.

Motor imagery and rhythmic judgment: '16, r, .07, p.e., .04.

These low correlations would be reflections upon the efficacy of imagery as an aid to precision if we could regard the test of rhythmic judgment as reliable.

Tonal memory and rhythmic judgment: '16, r, .22, p.e., .04.

Memory is a basic factor in rhythmic judgment.

Singing intervals and singing the keynote: '09, R, .45, p.e., .04; '16, r, .61, p.e., .03.

Singing the scale and singing the keynote: '09, R, .42, p.e., .04.

Voluntary control and singing the keynote: '16, r, .55, p.e., .03.

Singing and singing the keynote: '09, r, .76, p.e., .02.

Singing the interval, singing the scale, and voluntary control involve the same factors as singing the key, plus the interval concept and memory for this concept. This correlation shows that, as a rule, those who can sing the key at all accurately tend to sing the interval accurately.

Auditory imagery and singing the keynote: '16, r, .24, p.e., .04.

Motor imagery and singing the keynote: '16, r, .19, p.e., .04.

These fairly good correlations would seem to indicate that those who are ear-minded or motor-minded have an advantage in that they sing in key.

Tonal memory and singing the keynote: '16, r, .32, p.e., .04.

The general sense of pitch is a common element.

Musical training and singing the keynote: '09, R, .14, p.e., .05.

a. *Instrumental:* '09, R, .11, p.e., .05.

b. *Vocal:* '09, R, .26, p.e., .04.

This relatively small correlation in the first two items is indicative of the fact that the immediate reproduction of a tone is perhaps one of the most elemental forms of singing and speaking and therefore responds the least to training. The difference between the correlation in instrumental training and vocal training cannot be laid entirely to the value of training in voice. It is perhaps more due to selection; those who have a naturally good voice control are the ones who train.

Musical environment and singing the keynote: '09, R, .24, p.e., .04.

Training, heredity, and selection are perhaps responsible for the correlation.

Musical expression and singing the keynote: '09, R, .23, p.e., .04.

a. *Instrumental:* '09, R, .15, p.e., .05.

b. *Vocal:* '09, R, .24, p.e., .04.

Explanation same as for instrumental training and vocal training.

Musical enjoyment and singing the keynote: '09, R, .04, p.e., .05.

Absence of significant correlation here is indicative of the fact that few persons are able to detect their error in singing or in the singing of others, and enjoy music as it comes, not knowing what fine distinctions they fail to make.

Singing the scale and singing intervals: '09, R, .47, p.e., .03.

Practically the same factors are involved.

Voluntary control and singing intervals: '16, r, .32, p.e., .04.

The problems in these two factors are more unlike than it would at first seem. Interval depends upon memory concept whereas the least producible difference depends more largely upon pitch discrimination and motor control.

Singing and singing intervals: '09, R, .75, p.e., .02.

This large correlation is due to the fact that singing intervals was one of the measurements of which singing is the average.

Auditory imagery and singing intervals: '16, r, .40, p.e., .04.

This large correlation is very significant. Most observers upon close introspection find that the singing of intervals is not a blind leap but the auditory image is actually present in concrete form before singing.

Motor imagery and singing intervals: '16, r, .21, p.e., .04.

The ratio of this correlation to the preceding one represents approximately the rôle of motor and auditory imagery in the singing of intervals.

Tonal memory and singing intervals: '16, r, .30, p.e., .04.

Tonal memory was measured in terms of memory of intervals.

Musical training and singing intervals: '09, R, .23, p.e., .04.

a. *Instrumental:* '09, R, .39, p.e., .04.

b. *Vocal:* '09, R, .15, p.e., .05.

While vocal training furnishes good exercise in the learning of the interval, the interval is probably learned far more through listening to music than through the voluntary adjustment of intervals as in singing. In other words, we get our intervals largely from the piano and other common instruments in which they are most frequently heard.

Musical environment and singing intervals: '09, R, .18, p.e., .05.

Correlation may be due to training, heredity, and selection.

Musical expression and singing intervals: '09, R, .24, p.e., .04.

a. *Instrumental:* '09, R, .21, p.e., .04.

b. *Vocal:* '09, R, .28, p.e., .04.

Explanation same as for musical training. Vocal expression is of course essentially the singing of intervals. There is, therefore, both training and selection whereas in piano playing, *e.g.*, it is chiefly selection.

Musical enjoyment and singing intervals: '09, R, .05, p.e., .05. No correlation.

Singing and singing the scale: '09, R, .78, p.e., .01.

Musical training and singing the scale: '09, R, .18, p.e., .05.

Musical environment and singing the scale: '09, R, .16, p.e., .05.

Musical expression and singing the scale: '09, R, .31, p.e., .04.

Musical enjoyment and singing the scale: '09, R, .06, p.e., .05.

In singing the scale, the same principle operates as in the singing of the intervals, above.

Auditory imagery and voluntary control: '16, r, .29, p.e., .04.

Introspection shows very clearly that the auditory image is used in this test, often with profound consciousness, because there is a demand for imaging something which has not been heard.

Motor imagery and voluntary control: '16, r, .08, p.e., .04.

It is surprising that this correlation is not larger because introspection shows the motor image to be very conspicuous.

Tonal memory and voluntary control: '16, r, .50, p.e., .03.

This accords with introspections.

Auditory imagery and singing: '11, r. .07, p.e., .05.

Motor imagery and singing: '11, r, -.07, p.e., .05.

These absences of correlation suggest the need of more specialized inquiry into the actual efficiency value of images.

Musical training and singing: '09, R, .18, p.e., .05; '11, R, .09, p.e., .03.

None of the persons examined had enjoyed continuous professional training in singing; the fact that one had had a few more lessons than another is insignificant in comparison with the large differences in native capacity.

Musical environment and singing: '09, R, .22, p.e., .04; '11, R, .05, p.e., .03.

Musical expression and singing: '09, R, .32, p.e., .04.

Musical enjoyment and singing: '09, R, .01, p.e., .05; '11, R, .06, p.e., .03.

Compare these with correlation in singing intervals and voluntary control.

Motor imagery and auditory imagery: '11, r, .52, p.e., .04, '16, r, .42, p.e., .04.

All evidence points strongly toward a good correlation between auditory and motor imagery, much stronger, for example, than between motor and visual.

Tonal memory and auditory imagery: '16, r, .40, p.e., .04.

Naturally a good correlation. Tests of memory depend upon the ability to hold the group of tones in a single memory image for comparison.

Musical training and auditory imagery: '11, R, .21, p.e., .03.

Musical environment and auditory imagery: '11, R, .13, p.e., .03.

Musical enjoyment and auditory imagery: '11, R, .11, p.e., .03.

Auditory imagery responds to auditory environment of which musical training is a special form.

Tonal memory and motor imagery: '16, r, .16, p.e., .04.

Many observers remember in terms of motor processes to an extent which would lead us to expect a larger correlation.

Musical training and motor imagery: '11, R, .04, p.e., .03.

Musical environment and motor imagery: '11, R, -.03, p.e., .03.

Musical enjoyment and motor imagery: '11, R, .11, p.e., .03.

The correlation in the last item is small in view of the fact that the enjoyment of music is interpreted to a considerable extent in motor terms.

Musical environment and musical training: '07, R, .26, p.e., .05; '09, R, .30, p.e., .04; '11, R, .28, p.e., .03.

There is a tendency for those who live in a musical environment to take musical training.

Musical expression and musical training: '07, R, .51, p.e., .03; '09, R, .48, p.e., .03.

While the correlation is good, it shows that musical expression is in large part independent of musical training.

Musical enjoyment and musical training: '07, R, .22, p.e., .05; '09, R, .03, p.e., .05; '11, R, .10, p.e., .03.

If these two factors are regarded as standing in the relation of cause and effect, this correlation is low.

Musical enjoyment and musical environment: '07, R, .03, p.e., .05; '09, R, .15, p.e., .05; '11, R, .13, p.e., .03.

Musical enjoyment and musical expression: '07, R, .12, p.e., .05; '09, R, .16, p.e., .04.

Musical enjoyment and instrumental expression: '07, R, .13, p.e., .05; '09, R, .20, p.e., .04.

Does musical-education make a person hypercritical? Does recognition of failure in training tend to lower the estimate of musical enjoyment?

SOME GENERAL CONSIDERATIONS AND CONCLUSIONS

Certain general impressions have been gathered in the many years of work in this field; some of those that have direct bearing on the present situation should be mentioned.

Evolution in testing is a process of simplifying. In the test of consonance, *e.g.*, the first test was made with tuning forks and resonators under very complicated conditions of control. An elaborate system of weighting was devised for various degrees of consonance. All possible intervals within an octave were employed. The test was necessarily long. The definition of consonance was complicated. All these and some other requirements have given away to simple conditions. The test is now made with the piano. Only eleven intervals are selected and employed. The judgments are not weighted. The definition and the conception of consonance are simplified. Each of these steps in the direction of simplifying, except the resorting to the use of the piano, is a step in the direction of increased efficiency. This tendency is characteristic throughout our experience; improvement takes place through progressive simplifying of technique, delineation of problem, and statement of results.

The evolution of a test is a process of isolating and identifying a specific process. This is illustrated in the case of rhythm. Our so-called free rhythm and regulated rhythm are very unsatisfactory measures of rhythm as it appears in music and speech. Rhythm like memory falls into a number of distinct and separable factors. When we get each of these isolated and under control we shall perhaps not have any single test on rhythm as such, certainly not any to designate rhythm as a whole, for rhythm must be split up into its cognitive, affective, and motor components. Thus discrimination for time and intensity are basic. Temporal and intensive precision in action correspond to these on the motor side; but, in addition, mental content, tonal intellect, uninhibited impulse, temperament, subjective rhythm, and musical feeling in various aspects must be taken into account. Thus, as the testing of rhythm progresses, we shall tease out, from that bewildering tracery of mental pattern which we call rhythm, the component fibres; and, by testing each of these in isolation, we shall be able to learn a number of things in particular about rhythm, just as we are now coming into a position to say a number of things in particular about a larger conception of musical talent as a whole.

Evolution in testing is a progressive mastery of the means of commanding attention and effort under the most favorable conditions. The charge and a personal command of attention and effort in the person tested are most important factors in the test. The conditions must be so set as to take advantage of known principles of attention and effort in the grasping of the situation and responding to it and the charge, whether written or oral, must be not only emphatic but a matter of record as an element in the result; and unfortunately only persons with a certain gift of proficiency in handling others, trained to the intricacies of sources of error, and alert to incidental evidences which may appear, can be trusted to apply mental tests effectively. There is great danger of scrutinizing the physical and methodological aspects of the test and overlooking the important rôle of the personal charge which is necessary to bring into play the mental factor which is to be tested.

Evolution in testing is a progressive freeing from ambiguities. The children or adults who come in to be tested have few of the concepts of the experimenter. Learning how to put one's self in the place of the one to be tested is a power but slowly acquired. The blind complacency on this point of many of those who engage in mental testing is amazing. Progress comes through the slow education of the experimenter in this wonderful art of divining the point of view of the person to be tested, and technically stripping apparatus, method, and directions of sources of confusion. The instructions are not satisfactory merely because couched in words of a common language.

Evolution in testing is in the direction of making the test elemental whenever we are dealing with an innate capacity as distinguished from an acquired ability. This is characterized by the fact that to the extent that the test is elemental there should be no appreciable improvement with practice, development with age, or variation in general intelligence. Some tests may be made completely elemental. In others this characteristic can only be regarded as a goal which we may strive to approach. Of course the three factors named do not necessarily vary together. A test may be elemental in one respect and, in the others, only approach this in varying degrees. Since we cannot make all of the tests elemental for all three factors, it is important to know for any particular test to what extent the limit indicated by the record is merely cognitive in the sense defined in an earlier report (15), that is, does not represent physiological limit but is inferior on account of ignorance, lack of appreciation, unfitness of the test, and many other factors. Each of the tests here reported has been, as a rule, one hour in length. In this time it is possible to get permanently satisfactory records on the majority in a group, but there will always be a considerable per cent. who cannot be reached in that time. This is of course a grave source of error and is probably the chief source of discrepancy in correlation.

In view of the above considerations we are cautious in attributing significance to the correlations here found. In the period covered the tests have all been in a process of evolution. The correlations are themselves in many instances a criterion of the degree of efficiency in the test. In other cases the absence of correlation is a mark of accuracy in the tests. At best these findings should be regarded as a preliminary survey from which we may take our departure in more intensive critique of each test and its ramifications. We have found this preliminary survey exceedingly suggestive for guidance into further work and it is hoped that it may serve others in this field and in related fields in the same way.

With such reservations and apologies we may now attempt to gather some of the more salient features of interpretation for each test partly on the basis of the quantitative showing of the correlation but in general as a statement of impressions gathered in the experience with the tests. It should not be regarded as a full summary of what has been stated in detail.

Pitch discrimination—The test of this capacity may be regarded as elemental, that is, the physiological threshold (15) is independent of variation with practice, age, sex, or general intelligence. It must, however, be remembered that in a first rough test, as here used, the approximate physiological threshold is reached only in somewhat more than half of the cases.

This capacity is basic for all perceptions of pitch and for production of pitch in singing and playing, *e.g.*, the violin; also for consonance, auditory imagery, and to some extent for memory. The failure of close correlation with these in the present tests may be attributed to numerous factors among which are the following: the related test does not involve the least perceptible difference in pitch, *e.g.*, singing or playing in pitch when the error is due largely to lack of motor control, or consonance and tonal memory in which keen pitch perception is not essential for a moderate performance; the related test may not be effectively differentiated, *e.g.*, singing an interval in which the chief source of error may lie in an erroneous conception of the interval; in cases of poor records the threshold may be merely a cognitive one and the actual capacity may be used in the related test, *e.g.*, in singing the keynote.

For hearing ability and discrimination for intensity, the common element may lie in both the structural or pathological conditions of the ear; but in time-sense, the various forms of rhythm, and related tests it may often be traced to common central conditions or inadequacy of one of the tests.

The data in the questionnaire are of special interest on these points: musical training furnishes relatively little training in precision of pitch perception; musical environment makes but little difference except in so far as it is selective, because the experience of pitch differences is called into play far more frequently outside of music than in music; ability to perform and enjoy music in a moderate degree is not seriously limited by defective pitch discrimination, except in a comparatively small per cent. of cases; the report of enjoyment of music cannot have taken into account what the reporter has missed by not hearing, and may therefore represent a wrong conception of real enjoyment, jut as the color blind person has a wrong notion of what a color really is.

The measurement of pitch discrimination is undoubtedly facilitated by the presence of good auditory imagery, especially in a single group test. General intelligence also favors the securing of a good record. But there is no evidence to show that it correlates with actual psycho-physic capacity in pitch discrimination. In other words, lack of ear-mindedness and lack of general intelligence tend to produce unreliable record but they do not seem to effect actual psycho-physic capacity as functioning in familiar perceptions of sound. On the problem of heredity we have no satisfactory data.

Consonance.—Consonance is the most direct test we have on the ability to hear tone-quality. A test is now being developed for the measurement of the sense of timbre by measuring the ability to detect variations in the overtones. That ability is however closely related to the ability to judge the quality of two-clangs as in consonance, which is now the most general test of sensory capacity for musical intellect.

In view of this basic position of consonance as a test of the "ability to hear music" correlation with the returns from the questionnaire are of special interest. There is no evidence to show that those who have a natural sense of consonance are selected for musical training or that musical training and musical environment enhance this capacity; nor does a person's actual ability to hear tone-qualities as here measured seem to enter into his evaluation of his enjoyment of music. Our first move in the face of these facts was to question the validity and meaning of the consonance test. We are convinced of its validity both as to the isolation of factors concerned and fitness of method. The burden of squaring musical procedure with these facts is therefore passed on to the musical profession.

One of the most gratifying findings about this test is the surprising fact that it is elemental in several respects. This capacity is early present in bright children who have a musical ear. It is fairly independent of the vagaries of feeling, and measures a well defined type of sensory judgment which is developed by the every-day reactions to sound. It is, however, in some respects an intelligence test as no one can make a good record without the ability to sustain attention purposefully in a difficult act of comparison. Lack of ear-mindedness is also a serious deterrent in this test.

Physiologically consonance presupposes a certain degree of pitch discrimination. It involves the same sensory attitude as intensity discrimination though far more sustained. It is undoubtedly selective with reference to the various measures of rhythm in that the sense of rhythm, which is of motor origin, is naturally developed by those who have a keen ear for tone quality. Between time-sense and pitch of singing there is no close relationship; but, for quality of singing and playing we shall of course look for a strong correlation in future tests since the expression of five points of quality rests upon the hearing of them.

Intensity discrimination.—In normal hearing this is a clear-cut test of the intellectual capacity for accuracy in the observation of sound. It is the simplest test in the entire series and is elemental as to effect of training (16), sex, and age. It varies however with intelligence, of which it is a measure in one aspect. In this respect it is a test of the power of concentration of attention in its simplest form. This capacity may, therefore, be regarded as an index to general ability and reliability in sensory observation of sound. This measure therefore has two phases of definite significance in the evaluation of musical talent: it indicates intensity discrimination and it is an index to general ability and reliability in hearing of sound. The latter point is well sustained by the significant correlation our figures show for so many of the factors here measured in which there is no other basis of relationship than that of precision in the observation of sound.

Musically the capacity must be distinguished from a lively and imaginative play of intensity in the appreciation of music. Artistic musical hearing, like painting, rests ultimately, not on rigid sensory impressions, but upon a fertile imagination which takes the sensory impression as a cue. One who hears musically may be fantastic and fastidious in the intensity differences he attributes to sound and yet be inferior in the actual observation of such differences when they really exist; but, when it comes to singing or playing, this artistic license ceases and the effective performer is limited by his capacity for precision in the hearing of the shades of stress which he aims to convey.

Hearing ability.—This involves two variables, the relative sensitiveness of the physical ear as an organ and, as in intensity discrimination, the general power of attention to auditory perceptions. For the latter it is not so valuable as intensity discrimination because that is only one of the two variables and the other variable is the more important. Indeed the record of intensity discrimination should always be taken into account in the interpretation of hearing-ability as only one who has a good record in intensity discrimination can be counted on to reveal the actual physiological threshold in hearing-ability. The absence of correlation with so many of the tests here shown is therefore a mark of reliability in this test.

Time-sense.—There are three basic sensory aspects of music: pitch, intensity, and time. All other sensory aspects of music, such as timbre, consonance, and rhythm are complexes, in which one or more of these basic factors are elements. Time-sense as here used is the basic measure for the various temporal processes in the perception and expression of music. It complies with the requirements of a basic test in that it is simple and direct and is the most rigidly controllable measure available. Failure to correlate with the three so-called rhythm tests may therefore be regarded as a reflection upon the reliability of these, because time-sense is undoubtedly a basic capacity for all of them. The positive correlation with pitch discriminaion and intensity discrimination is evidence of the presence of that common element which intensity discrimnation measures.

Motor ability.—Motor capacity in music as well as in any other form of diversified action may be analyzed into five fundamental phases, namely, motor ability, precision in time, intensity and direction of movement, simple and complex reaction time, strength and endurance.

The conventional measurement of motor ability by means of the tapping with a key has a specious appearance of accuracy. On account of its basic position in motor control it is extremely desirable that this test should be analyzed and standardized more accurately before being used extensively in diagnosis. The test should be so divided into parts as to measure both speed and regularity. As here used the test involved only speed. But speed and regularity are the common elements which are involved in all tests of motor control. If satisfactorily isolated in this test, they may be regarded as furnishing a two-phased measure of general ability in motor control. Together they are a mark of the general tone or condition of the motor organism. Singing and playing in pitch, reaction-time, rhythmic action, and endurance, each involves these two factors.

The greatest problem in the development of the evaluation of this test now is to determine to what extent general motor capacity as thus measured can be interpreted as an index to the motor control of specific organs, such as the finger, the lips, or the vocal cords.

One of the greatest obstacles in the way of such an evaluation is the fact that we do not know the relation between voluntary use of a capacity and its automatic use. Our tests are all more or less voluntary, conscious reactions, whereas in artistic performances and, indeed, in all skill, both sensory and motor processes are more or less automatic.

Free rhythm.—The term rhythm as used in this and the next test should be discarded, and we should speak of time,—the time of free action, the time of regulated action, in order to recognize, first, the fact that on the motor side these are time tests, parallel to time-sense on the sensory side; second, to dispel the notion that these are primary tests of rhythm, which they are not.

This test is psychologically simple and can be made relatively elemental. It is easier to control than motor ability, yet we are not entirely satisfied with the test as here reported. Both the '11 and the '16 free rhythm and regulated rhythm tests were made by students, comparatively inexperienced in testing, and it was observed that they often failed in the very important matter of charge and command of mental attitude in the test. This situation emphasizes the fact that we may have perfected technique of physical method, and yet fail for want of personal command of the mental attitude in the observer. The notion that mental tests can be made so automatic as to eliminate the personal equation of the experimenter is absurd. This directs attention to the most urgent need in mental testing today—the need of not only formulating a charge, but of administering the test by a person who has strength of personality to make it effective, and technical insight enough to guard against unforeseen sources of distraction and variation in effort.

Regulated rhythm.—Psychologically, regulated rhythm is more complex than free rhythm and, therefore, is not so valuable. The failure to correlate with free rhythm and rhythmic judgment reflects unfavorably upon this test, because free rhythm represents the ability to play in correct time alone, and regulated rhythm the ability to play synchronously with another whose time is perfect, and rhythmic judgment is merely free rhythm one stage more complicated. These three tests, therefore, call for thorough revision.

We must be extremely cautious of the interpretation of the so-called rhythm tests, and not regard them as tests of rhythm in the sense of motor tendencies in the grouping of sounds by time and stress. The strongest kind of rhythmic person may be very inaccurate both in time and stress so far as the perception and feeling of rhythm is concerned, but when he attempts to convey his feeling to others by means of time he is limited by his power of precision in action which this test should measure.

Rhythmic judgment.—This test must be improved or rejected.

Singing the keynote.—This test is basic for all pitch singing. It is simple and precise, and, therefore, furnishes good opportunity for the accurate determination of many of the psychophysical principles involved in singing.

Most children who have a good ear develop this command very early so that the first imitations of musical pitch may be true, and may appear to be as automatic as if they had been inherited as such. True pitch comes to a child as early and as naturally as a vowel quality in speech, where the child has a natural ear for music and has sensitive motor control. There are, however, many and extraordinary exceptions to this rule. Occasionally a very bright person apparently cannot tell "tune" and much less sing in tune at all, and yet be educable in the singing of pitch. Such cases seem to be due to a sort of tone ignorance analagous to that obliviousness to odors which many of us display in the presence of good normal sensitiveness to smell.

This test correlates well with the other tests of singing, and may, therefore, be regarded as a general index to voice control of pitch. At its best, it rests upon pitch discrimination. It seems to be favored by auditory and motor imagery, and by tonal memory. The correlation with vocal training, musical environment, and vocal expression is, perhaps, in large part a matter of selection.

All the singing tests can of course be paralleled on an instrument such as the violin.

Singing intervals and singing the scale.—The test of singing intervals may, of course, be a test of any kind of interval, such as a natural scale, chromatic scale, melody, or any one or more isolated intervals, conventional or otherwise. It is a natural, accurate, and very satisfactory test. If it is to be used as a general measure of the control of the interval concept, the singing of the natural scale is perhaps the most satisfactory because the most familiar. The singing of intervals is highly favored by auditory imagery and tonal memory, also, to some extent, by motor imagery. It correlates well with musical training, musical environment, and musical expression. The latter two are probably both selective and effective in their relation to the singing of intervals. No relationship with musical enjoyment is revealed.

Voluntary control of pitch in singing.—This is the complement on the motor side to pitch discrimination on the sensory. This type of discriminative action gives promise of developing into a rôle possibly as important on the motor side as discrimination is on the sensory. This minimal sharping or flatting in singing can be paralleled in playing with any instrument of adjustable pitch. It answers the demand for a test that shall measure specific capacity in terms quite free from ordinary habit, and equally new to all. In this respect it differs radically from the singing of intervals or the keynote. Methodologically, it presents certain difficulties in securing a single measure in that there is no fixed standard as to the certainty of the change, but it seems that this difficulty can be overcome. This action involves primarily pitch discrimination and a form of motor control; it is favored by auditory imagery, motor imagery, and tonal memory, and it has many common elements with other singing tests.

Auditory imagery.—This is the only capacity in our series which does not lend itself readily to objective measurement. The introspective grading is, however, favored by the advantage of having fixed limits for the series of grades, namely, no image for the lower limit, and as vivid as true perception for the upper.

There are good unworked possibilities for the study of the nature of the true character of the musical make-up of an individual by an intensive individual study of the content, vividness, completeness, persistence, and spontaneity of the auditory imagery, particularly with the aid of some of the more recent forms of association tests.

It still remains to find out what rôle the auditory image really plays in the life of a musician, or in what respect it is essential to the highest appreciation of music. Unquestionably it holds a vital position in music, but the laws of its functioning and non-functioning are exceedingly complex.

In addition to the correlations already noted in preceding sections, we note here a conspicuous correlation with motor imagery and tonal memory. Records not included here show that motor imagery correlates far more closely with auditory imagery than with visual imagery.

Tonal memory.—This test is basic for the various phases of memory. It is clear-cut, rigid, simple, and adequate. If we shall have a single test for musical memory, this one answers the purpose, but a single test for such a complex act as memory must be regarded as a makeshift, since the various elements of memory must be isolated and tested separately, especially if intensive work is to be done.

Musical training.—In considering the returns of the questionnaire we have been cautious throughout to limit the applications to the degree of certainty implied in the character of the information itself. In correlating these facts with concrete measures from the objective tests it is equally important to limit the conclusions guardedly to the factor of talent actually controlled and measured, and to safeguard the conclusions in proportion to the accuracy of the analysis made by the test. Such precaution is necessary, not only for the writer, but it must also be borne in mind by the reader in his interpretation of statements like the following.

As far as the results of the questionnaire and supplementary evidences are reliable, we face a discouraging situation in the relation of the possession of musical talent and the opportunity for musical training. Briefly, we find that there is no satisfactory tendency to select the musically talented for musical training; that musical training does not ordinarily modify musical capacity; and that specific ability which might be developed by special training is not ordinarily enhanced by the training in vogue.

Musical environment.—The most impressive feature of the evidence before us on this point is the fact that the fundamental powers in musical talent such as pitch discrimination, intensity discrimination, time sense, imagery, and to some extent consonance, singing, and tonal memory, are developed quite apart from association with music. Musical training and environment seem to be a specialized form of the use of these capacities which are continuously in action in the appreciation of, and response to, an environment of sounds.

Musical expression.—It cannot be said from our evidence that it is the musically talented who play and sing for us, although there is some correlation in that direction.

Musical enjoyment.—The real absence of correlation between musical enjoyment, and musical talent and musical training throws new light on the validity of prevailing opinion in regard to the reality and quality of our musical enjoyment. It is conceivable that a person who could hear and feel nothing but the rhythm of a drum beat might get real enjoyment from that and rest undisturbed in the notion that he had enjoyed the full riches of music, because, like the color blind, his system seems complete and he knows not what lies beyond.

In the light of the facts we have reviewed, we may ask the same question for musical theory in general that is proposed in regard to rhythm in the latest book on that subject (8): "Is it any wonder that the student who dips, or, more boldly, dives into the inevitable chapter on rhythm to be found in current musical hand books, rhetorics, treatises about versification, etc., emerges mystified, when so little account is taken of individual differences in what is one of the most 'individually different' of human experiences?"

It is difficult to convey in writing the illuminating insight into, and concrete foundations for musical theory, art, and pedagogy that one obtains in the prolonged use of these tests. But the general fact can be made clear that the psychology of music must be founded and organized upon experimental analysis of musical talent, that the aesthetics of music must be built in a scientific spirit upon such experimental analysis of the operating psychological principles, and that the art of teaching and vocational guidance in music must be based upon established facts about the nature of talent, the nature of the learning processes, and the nature of the aesthetic principles involved.

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THE PERCEPTION OF CONSONANCE AND DISSONANCE

BY

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        The weighting of demerits
        The norm established
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The object of this investigation is first to establish the ranking order of the musical intervals within the octave c′c″ with respect to the degree of consonance, and second, to standardize a measurement of the perception of consonance.*

The term consonance has been variously defined, and has been used to convey several meanings. While in general, it

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has been used with reference to the agreement of simultaneous tones, we find each investigator or theorizer emphasizing some one factor in this complex phenomenon to the exclusion of one or two other factors of similar importance. This diversity of definition results in a corresponding diversity in the ranking order of the common musical intervals as to their degree of consonance. The method in this investigation will, therefore, be: first to determine the factors which enter into the perception of consonance, second, with these factors as a basis, to rank the intervals according to their relative degree of consonance or dissonance, third, to evaluate the ability to perceive consonance in terms of this ranking.

HISTORICAL

A brief resumé of the essential facts bearing most directly on this problem may be presented from the points of view of the theories and definitions of consonance, experimental methods, and ranking of intervals.

Definitions and experimental methods

Pythagoras discovered the regularity of the aliquot division of the vibrating string, and thereby gave a numerical value to the notes of the scale. Since then, the regularity of the vibration frequencies of tones has been known and accepted as a basis of consonance. No thought of the manner in which the mind perceives and distinguishes between consonances and dissonances occurred to the ancient Greeks; the perception was taken for granted. The pleasantness of some intervals and the unpleasantness of others were the only criteria that were present to their minds.

This conception prevailed even up to the time of *Leibnitz* (10) who was the first to call attention of scientists to the fact that the mind did not really analyze or perceive the actual number or the numerical regularity of the vibration frequencies in the intervals. Nevertheless, Leibnitz found no other explanation of this complex phenomenon in consciousness. Therefore, he appealed to the subconscious mind for a solution of the problem and came to the conclusion that the mind unconsciously calculated the ratios of the vibration frequencies.

"Die Musik ist ein verborgenes Rechnen des Geistes, welcher nicht weiss, das es zählt. Denn er tut Vieles mit verwirrten oder unmerklichen Perzeptionen, was er in deutlicher Apperzeption nicht wahrnehmen kann. Die irren, welche meinen, es geschehe nichts in der Seele, dessen sie selbst nicht bewusst sei. Obwohl also die Seele nicht fühlt, dass sie zählt, fühlt sie doch das Ergebnis dieser unmerklichen Zählung, d. h. das aus ihr fliessende Vergnügen bei den Konsonanzen, Missvergnügen bei den Dissonanzen. Denn aus vielen unmerklichen Übereinstimmungen entsteht das Vergnügen."

This unconscious calculation produces a consonant interval when the ratio number does not exceed five. "Wir zählen in der Musik nicht über fünf", says Leibnitz.

Euler (2) agreeing essentially with Leibnitz' explanation, interpreted the feeling of agreeableness of the consonances as due to the ease of perceiving order or coherence in the simpler ratios. He divided the consonances into ten classes, ranking them according to the simplicity of their ratios. Euler was the first scientist to formulate the fundamental law of consonance that "the degree of consonance is in a direct ratio to the magnitude of the common divisor of the vibration frequencies."

Schopenhauer (24) explained the mental processes that accompany the perception of consonances and dissonances in greater detail and regarded music as the highest expression of the divine in the world. It owes its great power to the essential relation which it bears to the human will. Consonances are the result of a rational relation of the vibration frequencies of two notes that can be expressed by small numbers. Their constantly recurring coincidences can be apprehended more readily by consciousness than those whose coincidences are less frequent. The notes, which are the result of this relation, blend. Dissonance is just the reverse of this state, but both consonance and dissonance comprise different degrees, the one shading into the other.

"Music is a means of making rational and irrational relations of numbers comprehensible, not like arithmetic by the help of the concept, but by bringing them to a knowledge which is perfectly, directly and simultaneously sensible. Consonances and dissonances, with their innumerable degrees of difference, portray the movements of the human will in its essential feelings of satisfaction and dissatisfaction."

The distinguishing factor of consonance would accordingly be this feeling of satisfaction portrayed by objectifying the movements of the human will through harmony.

The method of investigation with regard to musical intervals was theoretical, supplemented by but meagre and indeterminate empirical data, up to the time of *Helmholtz* (4), who gave an impetus to experimental investigation through his analysis of sound in the attempt to demonstrate that consonance is dependent upon the coincidences of upper partial tones which result in a relative absence of beats. The important criterion of consonance for Helmholtz is *smoothness*. His definition reads as follows:

"Consonance is a continuous, dissonance, an intermittent sensation of tone. Two consonant tones flow on smoothly, side by side in an undisturbed stream; dissonant tones cut one another up into separate pulses of tone." Consonance is dependent upon "certain determinate ratios between pitch numbers which do not give rise to beats, or only such beats as possess so minimal an intensity as to produce no unpleasant disturbance of the united sound."

On this theory Helmholtz constructed his consonance curve, showing the relative degrees of consonance on the basis of the number of beats possessed by the different intervals as quoted in Table I below.

As early as 1751 *Tartini* (27) called attention to the importance of combination tones, but it was left for Preyer to prepare the way for Krüger's exposition on the influence of difference tones on consonance.

Preyer's (21) experiments with tones, whose overtones and combination tones were excluded, tend to establish the fact that the feeling of pleasantness and unpleasantness of consonances and dissonances is dependent on the overtones and difference tones of the clang.

"The beats of the overtones and combination tones are," says Preyer, "a further criterion, for through them the smoothness of the sensation is destroyed. Yet they do not suffice to explain dissonances, as these occur without beats. The well recognized consonances must give the least combination tones, and the most unpleasant dissonances, the most; the former, the most coincidences, the latter, the least."

Stumpf is the pioneer in the purely psychological field, as he introduces a new point of departure. Stumpf (30) identifies consonance with tonal fusion:

"The sounding together of two tones approaches sometimes more, sometimes less, the impression of unity, and it is apparent that this is more the case, the more consonant the interval is. Even if we recognize the tones as two and separate from one another, yet they form a totality in the sensation, and this totality appears to us as possessing a greater or less degree of unity."

Thus Stumpf postulates "Verschmelzung" as the distinguishing criterion of the degree of consonance. He admits that other criteria exist, but this one factor is the only one necessary in ranking consonances and dissonances. Concerning this factor Stumpf writes as follows:

"Kann der Unterschied konsonanter und dissonanter Töne weder in unbewussten Funktionen noch in den Gefühlen liegen, so wird man ihn in den Tonempfindungen als solchen zu suchen haben, wo ihn denn auch Helmholtz suchte. Da er nun aber nicht in der begleitenden Obertönen und nicht in den Schwebungen liegen kann, so muss er eben in den beiden Tönen selbst liegen, welche wir konsonant oder dissonant nennen. Es ist, soviel ich sehe, nur ein Merkmal, das sich hier arbeitet: die *Verschmelzung* gleichzeitiger Töne."

As a correlate to his psychological theory, Stumpf proposes a physiological basis in his theory of "specific energy" which gives to each fusion its individual character.

Following out the theory that the better the consonance, the better is the fusion, Stumpf applied the technique of experimental psychology. That most consonant intervals are the most difficult to analyze into their constituent elements, is the basis of his method of analysis; and by this method he attempted to rank the intervals. He tested the perception of consonance with Appunn's Tonmesser and with the tones of the pipe organ, varying the quality of tone further by using the different stops of the organ, the observers being requested to record whether they perceived one or two tones, *i.e.,* whether or not the two objective tones served as one subjective. The number of errors for each two-clang constitute a measurement of the degree of consonance of that interval, and determined the ranking order.

Stumpf (29) found no difference between major thirds and sixths, yet he admits that there may be a fine degree of gradation between major and minor thirds and major and minor sixths. All the dissonances are ranked in one group as possessing the same degrees of dissonance, with the observation that the natural seventh, 4:7 may be a slightly better fusion than the other dissonances.

Stumpf (27) lays down the following laws of tonal fusion:

1. Fusion depends on the so-called ratio of vibrations.

2. The degrees of fusion are independent of the tonal region within the tonal range.

3. The degree of fusion is independent of the intensity, whether indeed it be the absolute or relative intensity, so long as the tones remain distinguishable.

4. The degree of fusion is not influenced by the addition of a third or fourth tone.

5. Very minimal deviations of the number of vibrations from the ratio create no perceptible difference in the degree of fusion. If the deviation is increased, the fusion in all pairs of tones, except the lowest degrees, passes into this degree without running through the intermediate degrees, if any. The rapidity of this transition is proportionate to the degree of the initial fusion.

6. Fusion remains and retains its degree when both tones do not affect the same ear.

7. Fusion remains in the mere representation of the imagination.

8. If we proceed above the octave, the same degrees of fusion recur with the ratio of vibrations increased one or more octaves. m : n 2x as m : n if m is less than n and x equals a small whole number.

Faist (3), following out Stumpf's method literally, attempted to verify these laws of fusion, in experiments on the pipe organ with the use of its different stops. In a preliminary experiment he employed what he termed "the direct method", *i.e.,* "the method of serial rank, in distinction from the indirect method used by Stumpf. This method involves the ranking of the intervals directly, keeping the whole series in mind and giving them their relative rank. The result of Faist's experiments tended to verify all of the laws postulated by Stumpf, except the third. He found that the relative intensity of the components of the interval did influence the perception of fusion.

Both *Meyer* (14) and *Stumpf* (34) have also attempted to measure consonance by means of reaction time. The consonances were always distinguished from the dissonances but this method showed no consistency in the ranking of the other intervals, and it was rejected by Meyer as unreliable. Meyer also investigated the effect of variations in intensity, and found that the less consonant the intervals are, the greater is the difficulty of recognizing them in their minimal intensity, and that the relative loss of intensity of higher tones synchronous with lower tones has no perceptible influence within the octave. As to the effect of presenting one tone to each ear, for the purpose of excluding the difference tones, Meyer affirms that this exclusion results in a loss of ability to rank the more difficult intervals, although consonances are readily distinguished from dissonances.

Buch (1) criticizes Stumpf for neglecting to regulate the conditions of his experiments. He thinks it unlikely that experiments made with the organ of the "Domkirche in Halle" could be carefully enough regulated to be trustworthy. Accordingly, Buch constructed a special instrument, using the organ, by means of which he regulated the intensity, duration, and pitch of the intervals. His experiments were made with, and without analysis. He makes a distinction between making a judgment from the point of view of analysis and that of synthesis. He developed a twofold ranking of the intervals, one on the basis of fusion, and the other on the basis of smoothness.

Lipps' (11) explanation of consonance is based on the rhythmic coincidences of the tonal series. The rhythmic coincidences have their correlate in the psychic processes. For our immediate consciousness, consonance appears as an agreement in unity, or, as Lipps expresses it, "eine Zusammengehörigkeit, eine einheitlichkeit". Furthermore, it is an agreement that gives rise to a feeling of satisfaction. "Consonanz ist ein Verhältnis zwischen Tönen in dessen Natur es liegt, Befriedigung zu erzeugen." The most perfect consonance does not give rise to the most satisfaction as it is "empty and monotonous."

Meinong and Witasek (8) introduced the method of "paired comparisons" in determining the ranking of the intervals, as played on the tones of the violin. They state their conclusion briefly as follows:

"... zwei Töne um so mehr verschmelzen, (a) je näher ihnen der Klang steht, auf den als Partialtöne bezogen werden können, (b) je grösserer Zahlenwert dem Verhältnis ihrer Schwingungzahlen zukommt."

Their results are interpreted in terms of the Ebbinghaus theory of hearing. Their experiments demonstrate that the method of paired comparisons may be used to good advantage in the testing of the perception of the degree of consonance and the ranking of the intervals. Meyer has questioned the reliability of their results because of the inaccuracy of the violin as to pitch.

Using the method of "paired comparisons" with the tones of Appunn's Tonmesser, tuned to the accuracy of 1 v.d., *Pear* (19) determined the ranking of the intervals in degree of consonance. The observers recorded the intervals compared as equal, plus, minus, or doubtful in preference, and the ranking order was computed on the basis of the number of "votes" given each interval. He considered fusion, analyzability, pleasantness and unpleasantness, and association, the factors which might enter into the perception of consonance. These factors were explained and illustrated for the observer, and he was instructed to make his judgment on the basis of fusion."

Wundt's explanation (41) shows that consonance is dependent on the confluence of various factors. There are four criteria that are more or less essential conditions of this phenomenon, namely: (1) Purity, the number of primary difference-tones of different orders, which combine to give the consonant chords a distinct or individual character; (2) uniformity, the uniform relation of the intervals to the compass of the scale; (3) the discrimination of consonance by the recognition of the tonal elements, dependent on the direct and indirect relation of clangs; (4) the fusion of tones into a "clang unity" through the dominance of one of the tonal elements—the one which arouses the most intensive associations.

Wundt explains dissonance as a "diffuse tonal fusion." The diffuse nature of dissonance arises, on the one hand, from the physiological condition of tone absorption; on the other, psychologically, through the distinct differentiation of tones arising from the compounding of the interfering difference-tones. Consonance is, therefore, an act of the apperceptive faculty of mind, which synthesizes the tones into a unity. The attention concentrates on the tonal element that carries with it the strongest associations, and brings all the related phenomena to a focus with the same.

Krueger (8) adopts the first criterion of Wundt as the explanation of consonance and dissonance. A two-clang always possesses five difference-tones. The pitch of each is determined by the formula h-l, 2h-l, 3h-l, etc. These difference-tones are related to every other simultaneous tone in the clang exactly in the same manner as the simultaneous primary tones. Thus, coincidences, beats, intermediate tones result from these difference-tones, and influence our perception of consonance. The best consonances are those that are characterized by the absence of distinct difference-tones. Dissonances are the result of difference-tones in the two-clang which interfere with one another. The degree of dissonance depends on the number of these interfering difference-tones.

Krueger (6) bases his theory on empirical data. His method of experimentation had for its object the determination of the number and pitch of the difference-tones present in the various intervals. In order to exclude the overtones, he used the tuning forks. The observer was requested to record the number of difference-tones in each interval, and to identify the pitch of each on a Tonmesser.

Stumpf (29) has criticized Krueger's results as not showing sufficient consistency to substantiate his theory. As another proof against the theory he states that consonance and dissonance are perceived even when the tones composing the two-clang are presented one to each ear, thereby excluding the possibility of difference-tones.

To sum up the historical review, we have gathered the data into a table by different authorities and methods, showing the order of consonances and dissonances:

This historical summary shows that the factors emphasized in the course of investigating this complex phenomenon have been: the feeling of satisfaction, agreement of tones, smoothness, fusion, and purity, with slight variants of these. We recognize the fact throughout that the order of the intervals tends to correspond to the simplicity of the ratios, expressing this mathematical relationship. That the feeling of satisfaction, or the feeling of pleasantness, is too variable and general a factor to be used as a constant criterion, is evidenced by the fact that it has not entered as a determining factor in any of the experimental investigations.

The most fundamental factor in ranking consonance and dissonance may be termed *blending,* the tendency of tones to merge into a composite tone that shows a more or less distinct agreement of constituent parts in so far as they are perceived

Ranking of Intervals TABLE I—*Historical order of consonances and dissonances*

Authors	*Date*	*Instrument*	No. Intervals…… *Method*	Math. ratios*…… *Criteria*	1:2 $c'c''$	2:3 $c'g'$	3:4 $c'f'$	4:5 $c'e'$	3:5 $c'a'$	5:6 $c'e'^{b}$	5:8 $c'a'^{b}$	5:7 $c'g'^{b}$	9:5 $c'b'^{b}$	9:8 $c'd'$	15:8 $c'b'$	15:16 $c'd'^{b}$
Franco of Cologne	12th cent.		Theoretical	Pleasantness	1	2	2	3	4	3	4	5	5	5	5	5
Euler	1739		Mathematical	Pleasantness	1	2	3	4	5	6	7	8	9	10	11	12
Helmholtz	1863	Various	Coincidences of upper partials Beats	Smoothness	1	2	3	5	4	6	7	8	9	8	10	11
Stumpf	1883	Pipe organ (Different stops)	Analysis	Fusion	1	2	3	5	4	6	7	8	9	8	10	11
Faist	1897	Pipe organ (Different stops)	1) Direct 2) Analysis	Fusion Fusion	1	2	3	4	4	4	4	5	5	5	5	5
Meinong and Witasek	1897	Violin	Paired comparisons	Fusion	1	2	3	5	6	9	4	7	8	10		
Lipps	1899		Theoretical	Rhythmic coincidences	1	2	3	4	5	6	7	8	9	10	11	12
Buch	1900	Pipe organ Tonmesser	Analysis	Fusion Smoothness	1	2	3	3	3	4	4	4		5	6	
Krueger	1903	Tuning forks	Analysis	Purity	1	2	3	4	3	6	5	5	4	7		
Pear	1911	Tonmesser	Paired comparisons	Fusion	1	2	3	4	5	7	6		8	9	10	11

* The mathematical ratios are in some cases only approximate, *e. g.* the ratios for $c'g'^{b}$ and $c'b'^{b}$, 5:7 and 9:5. The ratios differing slightly for the different authorities.

as members. This term has been used by some authorities as synonymous with consonance and to express the agreement of tones. The recurrent similarities of which the early scientists spoke and which Schopenhauer and Lipps have emphasized might also be classed under the category of blending. Preyer, Wundt, and Krueger have emphasized the importance of purity as a criterion and it has proved to be a specific mark of the agreement of the component tones.

Authorities agree with respect to the ranking of the octave and the fifth, first, and second, respectively; but, for the remaining intervals, we find disagreements due to the quality of tone, to the variation of the method of investigation, and to the variation in the basis of judgment.

It may never become possible to arrive at absolute agreement in the order of ranking, but it is plain from this brief historical survey that much may be gained in that direction by a clearer conception in regard to the nature of consonance, the analysis of conditions, and specific definition of terms for the purpose of experimental control. This will be the object of our next part.

ANALYSIS AND RANKING OF INTERVALS

The following series of experiments are the result of two years of investigation in the psychological laboratory of the State University of Iowa, extending from the fall of 1911 to the fall of 1913.

Preliminary Study of Apparatus

In a preliminary series of experiments, the reed organ, the pipe organ, blown bottles, the dichord, tuning forks, and the piano were tested with reference to their adaptability and efficiency in producing tones for an accurate measurement of the perception of consonance. Ten experienced observers were given the test, here designated as Series A, and were requested to give introspections with regard to the quality of tone. The recommendations which follow are based on this ranking and the introspections of the observers.

The reed organ was supplied with a set of accurately tuned reeds, even temperament. The pipe organ pipes were of the open wooden type, producing a soft mellow tone. These were tuned to correspond to a set of forks tuned in just intonation, or forks of even temperament as the case required. The "blown bottles" were selected instead of the Stern tone-variators on account of their being more easily manipulated, *i.e.,* it was possible to have a complete series tuned permanently. This apparatus consisted of ordinary bottles of cylindrical shape, which, when empty, gave approximately the tone of c′, 256 v.d. They were tuned in just intonation by filling with paraffin. The mouthpieces were firmly attached to the bottles. The organ pipes and the "blown bottles" were energized by compressed air under constant pressure.

The dichord (Spearman's) was strung with a heavy piano string (wound wire), and was sounded by stroking with a cello bow. The wound string responds more readily, and the heavy cello bow eliminated the harsh and grating overtones and noises incident to the use of the ordinary wire string and the lighter bow of the violin. To avoid changes in the quality of the tone, the dichord was played in a uniform manner, care being taken to stroke the string evenly near the bridge.

In the early experiment, the forks were sounded mechanically before carefully attuned Helmholtz resonators, but later by a free movement of the hand. In the most successful mechanical devices, the handles of the forks were firmly mounted in rubber casings before the resonators, and were struck by means of hammers, mounted on steel springs. Wooden, cork, rubber and the regular felt piano hammers were tested, and the piano hammer was selected as producing the clearest tone. But, in spite of precautions, the thud incident to striking the fork, proved a distraction and caused impurities and, therefore, presentation by hand proved to be the best method.

The nine intervals, c′c″, c′e′, c′f′, c′g′, c′d′, c′e′, c′a′, c′b′♭, c′d′, were studied as sounded by each of these three instruments in two extensive series, (1) by the method of paired comparisons, and (2) by Stumpf's method of direct analysis; *i.e.,* in the former series, relative consonance was judged for successive pairs upon each of the factors which may constitute consonance, and in the latter a direct judgment was based on fusion alone.

The reed organ was finally rejected because the tone was somewhat harsh and difficulty was experienced in securing a uniform timbre of the tone throughout the octave. The dichord was found impracticable as, beside showing variations in quality with slight variations of pressure and adjustment in bowing, it requires a change of the bridge for each note and is difficult to manipulate. The blown bottles, while producing a clear tone, presented difficulties in regulation. *Sylvester* (37) demonstrated that the pitch of a blown bottle is very difficult to control but we found that variations in the relative intensity of sound and the timbre were far more difficult to control. The inevitable difference in timbre made the tones stand apart in the two-clang in such a way as to be prohibitive.

The instruments available for the test were found to be the piano, the tuning forks, and the pipe organ.

The test of consonance with a rich quality of tone can be given more expeditiously by the piano than by the dichord. The piano offers an advantage in its availability and in the perfection it has reached as a musical instrument. It also has the advantage of being familiar and agreeable. Most of the sources of error, which may arise in the use of the piano, can be effectively guarded against. As three strings are sounded for each tone, each of these must be accurately tuned so that no beats arise in the single tone. The same end may be gained by damping two of the strings, thus leaving only one to vibrate. An accurate piano tuner can, however, eliminate the beats that are present in the single tones of the ordinary piano. To eliminate many of the impurities that may arise from resonance, the soft pedal should be used continuously in the test.

The organ pipes present the difficulty of regulating the wind pressure so as to keep it constant. As with the blown bottle, the variations in intensity and in the adjustment of lips causes considerable variations in the pitch. Uniformity of pressure and accurate adjustment is accomplished in the regular pipe organ by a rather complex mechanism, which it is difficult to improve upon in the laboratory. It is, therefore, best to use a good organ where access to one can be had. The pipe organ of the Methodist Episcopal Church of Iowa City which we used, is a modern two-manual organ, which was in good condition. The most favorable stop for this experiment was found to be the "stopped diapason" which gives a tone intermediate in richness between the rich tones of the piano and the pure tone of the tuning fork. The tones of the organ are, however, not so clear-cut as the piano and tuning fork tones. Therefore, the observer has not the same certainty in his judgments of the organ tones as of the piano or tuning fork tones. Simultaneity in sounding the tones was regulated by opening and closing the stop after the keys of the interval had been pressed down.

The tuning forks are the most reliable in both pitch and timbre. If presented by hand, in a uniform manner, they give clear and distinct tones, which are especially well adapted for a test of consonance. The tuning forks used in these tests were accurately tuned to the tempered scale. The frequencies as recorded on the tonoscope registered: c′—258.6, d′♭—274, d′—290, e′♭ — 308, e′ — 326, f′ — 246, g′♭ — 364, g′ — 387, a′♭ — 410.14, a′ — 435.9, b′♭ — 460.8, b′ — 487.8, c″ — 517.2. Precautions were taken to secure pure tones by sounding the forks in a uniform manner before tuned Helmholtz resonators. The twelve resonators were mounted on the rim of a wheel and the c′ set on the center so that by giving a turn to the wheel any one of these in the rim could be swung into position horizontally to the right of the c′.

In the preliminary experimentation on the quality of the tone, two general facts were fairly well demonstrated. First, it was shown that the ranking of consonance will vary slightly for different qualities of tone. This is expressed quantitatively in later experiments. Second, when by the use of two sets of tuning forks, the just intonation was compared with the tempered intonation, no difference in ranking of the intervals large enough to affect the order resulted from the difference in temperament. This conclusion agrees with Faist's (3) statement with regard to minimal variations in vibration frequencies.

Criteria of consonance and dissonance

It is clear from the historical survey, and it was demonstrated in the preliminary experiments, that the fundamental reason for the great divergence in the ranking by experts and the consequent disparagement of the ranking of consonance and dissonance has been due to the failure to take common ground in the definition of these terms. Our first step was, therefore, to put the various claims of factors involved to a test in a long and painstaking series of analytical tests in which the various possible factors of criteria were isolated and discussed critically under control. This preliminary inquiry resulted in the recognition of the following factors:

For consonance:

1. Blending—a seeming to belong together, to agree.
2. Smoothness—relative freedom from beats.
3. Fusion—a tendency to merge into a single tone, unanalyzable.
4. Purity—resultant analagous to pure tone. (See Wundt.)*

For dissonance:

1. Disagreement—incompatibility.
2. Roughness—harshness, unevenness or intermittence.
3. Disparateness—separateness or seeming to stand apart—analyzable, "twoness".
4. Richness—resultant analogous to rich tone.

In terms of these factors we may then define consonance as follows: *When the two tones of a two-clang tend to blend or fuse and produce a relatively smooth and pure resultant, they are said to be consonant.* Dissonance is the reciprocal of this. "Agreeableness" which has played an important rôle in the popular conception and in the theory is here conspicuous by its absence. The perception of consonance as above defined therefore becomes a cognitive act of discrimination rather than a mere feeling of agreeableness.

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* Restfulness—a feeling of completeness, finality or satisfaction, with its opposite disquietude—a feeling of incompleteness, needing to be resolved, was first adopted as a fifth criterion, but it soon developed that it must be dropped as it is a variable criterion directly due to progression and association, which must be excluded.

Method of procedure

The above definition, with its analysis into blending, smoothness, fusion and purity displayed on a chart, was read and discussed, giving all of the observers a consistent understanding of the definition.

The observers were instructed to judge each "two-clang" as an aesthetic object by itself, without respect to the effect of progression, meaning, association, or mood, and to make their judgments on each of the above given criteria in turn in separate series of experiments for each of the four criteria.

The experiment was made "with knowledge", and was conducted on the plan of an informal seminar, allowing a discussion of each judgment, but each observer recording his own final judgment. The intervals were sounded simultaneously, with a duration of approximately two seconds, and were repeated as often as requested by any observer—sometimes as many as fifteen or twenty times.

In determining the constant factors that enter into the perception of consonance and the ranking of the musical intervals, one must rely on the introspection and judgment of experienced observers of different types. For this experiment, therefore, eight observers were carefully selected on the basis of their training and fitness for the work.*

Even with the definition of consonance and the control of procedure here adopted, there remain many points of doubt and individual differences in opinion among observers as to the order of consonances. Since it was necessary to arrive at one particular order which might be considered a norm, the observers adopted the plan of sitting together in the experiment, proceeding very slowly, and discussing all cases of doubt or difficulty, analyzing the situation, varying the conditions of stimulation, and refining observations. This proved a very great advantage since each of the eight observers, of different types of training, offered to one another criticisms and suggestions for points of view and in this way distinctions were developed and errors of observation were eradicated which might otherwise have passed unnoticed.

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* They were the following: Professor C. E. Seashore, Assistant Professor Mabel C. Williams, Professor Edward Schaub, and Professor Robert Fullerton, Dr. Alma D. Schaub, Dr. Thomas Vance, Mr. Hazelette and the writer. Professors Seashore, E. Schaub, and Williams and Fullerton were members of the faculty, the last named being the head of the Department of Vocal Music. Dr. Thomas F. Vance was an advanced student in Psychology; Dr. Alma Devries Schaub had taken her Ph.D. in Psychology; and Mr. Hazelette was a graduate student in Physics and an experienced flute player.

Statement of results

As a group of trained observers, we found no difficulty in four-fifths of the sixty-six cases of paired comparisons at the beginning, and, after discussion, the differences of opinion centered about a still smaller number of the cases. Since each observer recorded for himself, we secured eight individual sets of ranking, although all of these were materially modified by the enlightment which came through mutual criticism and the repetition of trials. The record showed for each observer the ranking of the intervals for piano, tuning-fork, and pipe organ, and on each of the four factors, blending, smoothness, fusion, and purity separately. This series we may designate as *Series B*. The results will be stated in Table III after the results of the final test, *Series C,* have been stated in Table II.

It was the original intention to accept the average of these records (Table III) as a norm, but the discussion and mutual criticism was so stimulating and interesting that all the observers agreed to sit again and continue by the same method until all should agree and a unanimous verdict could be handed in as in the case of a jury. This was done with the piano and tuning-forks separately in what is here designated as Experiment Series C. The pipe organ was left out to shorten the labor, in view of the fact that the observers were of one mind that the piano and the tuning-forks were the best instruments available for the rich tones and the pure tones respectively.

The final returns in this series (C) are condensed in Table II, where the record is kept for piano and organ for each of the eleven intervals on blending, smoothness, fusion, and purity in terms of the number of times a given interval was preferred. Since there were twelve intervals, the one that was preferred to every other would have a record of 11, meaning that it was preferred to eleven other intervals, the next one would be preferred to ten other intervals, etc. The actual rank is, therefore, approximately the inverse order of these numbers as is indicated by the Roman numerals.

The intervals are given in this table in the order in which they rank for the piano in the average.

It is manifestly out of the question to combine the ranking on fusion with the ranking of the other three criteria since the former results in a peculiar classification of its own. The other three criteria, however, seem to work together, prove mutually supplementary, and result in a fairly similar order of ranking. (See Table II). These are, therefore, brought together through the average in the last column of Table II, (Fig. 8), which may be regarded as the goal of the experiments in this Part on the order of ranking.

The data of this table are illustrated in Figures 1-8, which are self-explanatory and will aid materially in the interpretation of the table.

Table II is the principal table of facts to be considered here, but Table III is inserted for two purposes: (1) to furnish the tentative data for the pipe organ tones, and (2) to show to what extent the order of rank in Series C deviates from that of Series B (Table II).

The rank for the organ tone stated in Table III would probably not have changed very much if this tone quality had been carried through Series C as was done with the piano and tuning-forks. The change of relative rank for the piano and the tuning-forks from Series B to Series C may be seen by a comparison of these two tables, those in Table III representing the average of independent judgments of the eight observers and Table II the unanimous verdict reached later by the same observers.

While there are normal variations in the figures which denote

		Blending		*Smoothness*		*Fusion*		*Purity*		*Total* {Blending Smoothness Purity	
c'c''	P.	11	I	11	I	11	I	11	I	11.0	I
	F.	11	I	11	I	11	I	11	I	11.0	I
c' g'	P.	10	II	9	III	8	V	9	II	9.3	II
	F.	10	II	9	III	6	III	10	II	9.7	II
c'a'	P.	6	VI	10	II	3	VIII	7	IV	7.7	III
	F.	7	VI	10	II	2	VII	8	III	8.3	III
c' e'	P.	9	III	7	V	6	V	5	V	7.0	IV
	F.	8	IV	7	IV	7	IV	5	V	6.7	V
c' f'	P.	7	V	6	VI	5	VI	8	III	7.0	V
	F.	9	III	7	IV	7	IV	5	V	7.0	IV
c' a'^{b}	P.	5	VII	8	IV	3	VII	5	V	6.0	VI
	F.	6	VI	7	IV	3	VI	6	IV	6.3	VI
c' e'^{b}	P.	8	IV	5	VII	8	IV	2	VIII	5.0	VII
	F.	5	VII	3	VII	7	IV	3	VI	3.7	VII
c' g'^{b}	P.	4	VIII	4	VIII	4	VII	3	VII	3.7	VIII
	F.	4	VIII	5	V	4	V	3	VII	4.0	VIII
c' b'^{b}	P.	3	IX	3	IX	1	IX	4	VI	3.3	IX
	F.	3	IX	4	VI	1	VIII	3	VII	3.3	IX
c' d'	P.	2	X	1	XI	9	III	2	VIII	1.7	X
	F.	2	X	1	IX	8	III	1	IX	1.3	XI
c' b'	P.	1	XI	2	X	0	X	1	IX	1.3	XI
	F.	1	XI	2	VIII	0	IX	2	VIII	1.7	X
c' d'^{b}	P.	0	XII	0	XII	10	II	0	XI	0.0	XII
	F.	0	XII	0	X	10	II	0	X	0.0	XII

TABLE III—*Rank of consonances and dissonances (Series B)*

		Blending		*Smoothness*		*Fusion*		*Purity*		*Total* {Blending Smoothness Purity}	
		av.	m. v.	av.	m. v.	av.	m. v.	av.	m. v.	av.	m. v.
c′ c″	**P.**	10.9	.2	11.0	.0	10.5	.7	11.0	.0	10.9	.2
	F.	11.0	.0	11.0	.0	11.0	.0	11.0	.0	11.0	.0
	O.	11.0	.0	11.0	.0	10.8	.3	11.0	.0	10.9	.1
c′ g′	**P.**	9.0	1.0	9.0	1.0	5.6	.9	9.3	.9	8.2	.9
	F.	9.9	.2	9.4	.5	6.3	1.6	9.6	.5	8.8	.7
	O.	9.6	.6	9.4	.8	6.6	.9	9.3	.6	8.7	.7
c′ a′	**P.**	6.8	.5	7.5	.8	3.0	.5	7.3	.6	6.2	.6
	F.	6.0	.7	7.1	.7	2.8	.8	7.5	1.0	5.9	.8
	O.	6.0	1.0	6.8	1.3	2.8	.6	7.0	1.0	5.7	.7
c′ e′	**P.**	8.8	.6	7.5	1.1	7.1	.4	7.3	.9	7.7	.8
	F.	8.4	.5	7.5	.6	7.0	1.0	7.0	1.0	7.5	.8
	O.	9.0	.3	7.1	1.2	6.5	1.3	8.0	.8	7.7	.9
c′ f′	**P.**	7.6	1.0	6.8	.8	4.9	.7	7.4	1.3	6.8	.9
	F.	7.9	.2	6.0	.8	6.0	.3	6.5	.8	6.6	.5
	O.	7.9	.5	7.3	1.1	5.1	.7	6.9	.9	6.8	.8
$c'\,a'^{b}$	**P.**	6.1	1.2	6.5	1.0	3.1	.7	6.4	1.3	5.5	1.0
	F.	5.5	.8	6.5	.9	2.8	.4	6.6	.8	5.4	.7
	O.	4.6	.5	5.3	.9	3.1	.7	5.9	.4	4.7	.6
$c'\,e'^{b}$	**P.**	6.1	.4	4.8	1.0	6.1	1.4	4.1	.7	5.4	.8
	F.	5.9	.2	2.5	.8	7.5	.6	4.3	.6	5.1	.6
	O.	6.9	.4	5.0	.8	7.0	1.0	4.4	1.0	5.8	.8
$c'\,g'^{b}$	**P.**	4.0	.0	4.1	.2	3.5	.8	4.3	.9	3.9	.5
	F.	4.9	.7	4.4	.9	4.1	.7	3.8	.4	4.8	.7
	O.	4.8	.8	4.8	.6	4.1	.9	4.0	.4	4.5	.7
$c'\,b'^{b}$	**P.**	2.6	.5	2.9	.2	1.0	.0	3.6	1.3	2.5	.5
	F.	3.0	.0	3.8	1.9	1.0	.0	3.8	1.2	2.9	.8
	O.	3.0	.3	3.1	.9	1.6	.6	3.6	1.7	3.8	1.1
c′ d′	**P.**	2.4	.7	1.4	.5	6.9	1.7	2.0	.3	3.2	.8
	F.	1.9	.2	1.0	.0	7.0	.5	1.0	.0	1.4	.2
	O.	1.3	.4	1.3	.4	8.1	.7	1.3	.4	3.0	.6
c′ b′	**P.**	.6	.3	1.5	.5	.3	.0	1.0	.0	.9	.1
	F.	1.1	.2	2.0	.3	.0	.0	2.1	.2	1.3	.2
	O.	2.0	.3	1.8	.6	.3	.2	2.8	1.5	1.7	.3
$c'\,d'^{b}$	**P.**	.0	.0	.0	.0	9.8	.4	0.0	.0	2.5	.1
	F.	.0	.0	.1	.1	9.8	.4	.1	.1	2.5	.2
	O.	.0	.0	.0	.0	9.3	1.0	.0	.0	2.3	.3

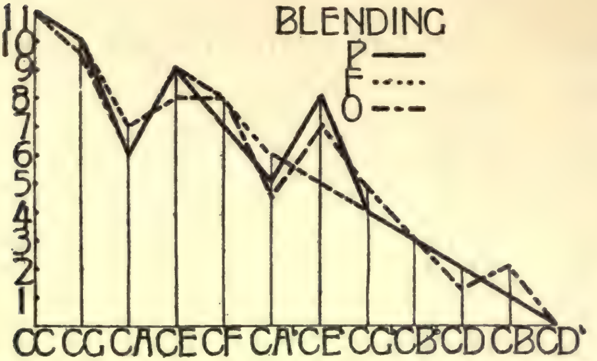

FIG. 1. Blending, for piano, forks, and organ respectively.

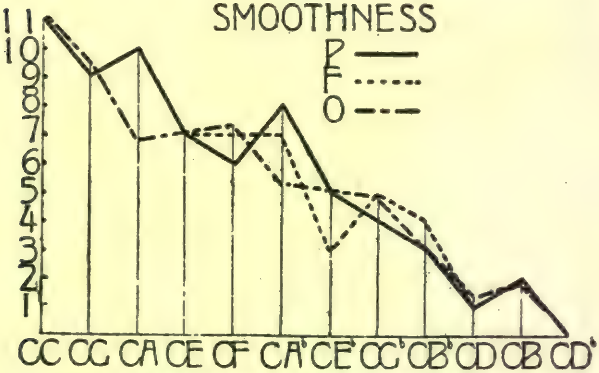

FIG. 2. Smoothness, for the three instruments.

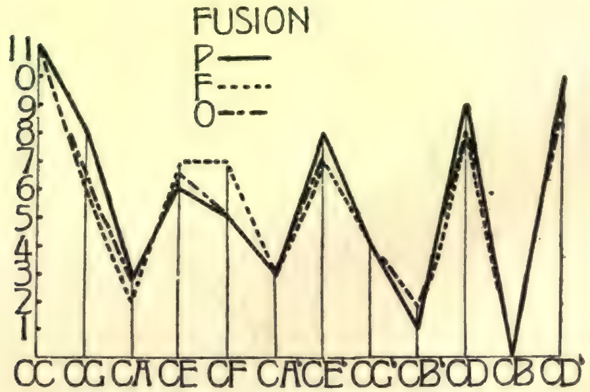

FIG. 3. Fusion, for the three instruments.

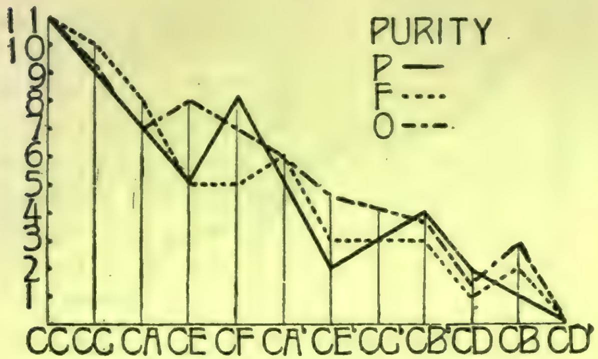

FIG. 4. Purity, for the three instruments.

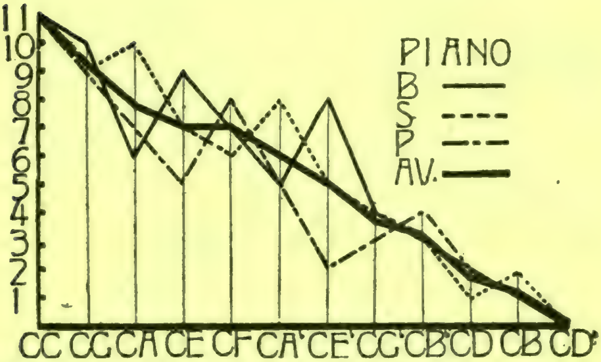

FIG. 5. Blending, smoothness, and purity, with the composite (Av.) from these for the piano.

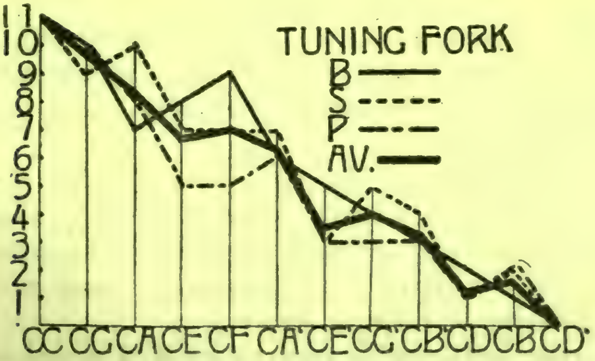

FIG. 6. Blending, smoothness, and purity, with the composite from these for the tuning forks.

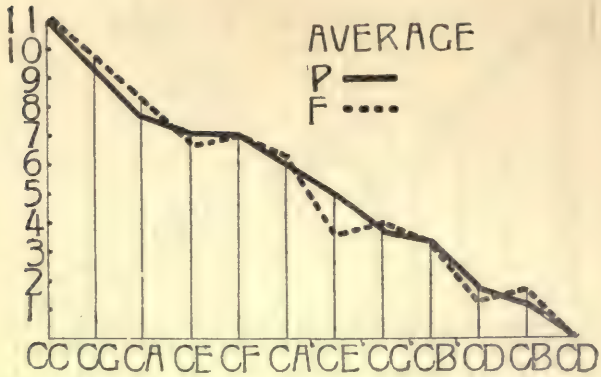

FIG. 7. Comparison curves for piano and tuning forks.

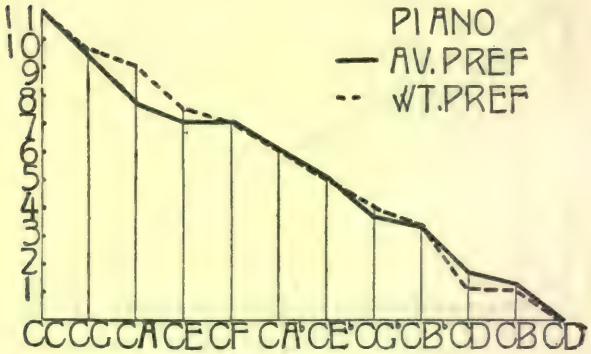

FIG. 8. Comparison of the average preference and the weighted average preference for the piano.

the number of preferences, few of these are enough to alter the order of rank. The nature of the change and the quantitative difference may readily be seen by comparing corresponding figures in the two tables.

The mean variation of the preferences in Series B is given in Table III in order to convey some idea of the variability in individual decisions by different observers. The mean variation may also be regarded as showing, to some extent, the relative difficulty of different intervals.

One further step should be taken: a group of trained observers should proceed as in Series B and C above, except that only one decision should be rendered for the three criteria on the following basis: *Give the decision on blending alone if the degree of blending is perceptibly different; if not, make the decision on smoothness; and, if there is no difference in either smoothness or blending, base the decision on purity.*

That procedure has the merit of basing the decision on a single criterion—the appropriate one in each case—instead of striking an average of three. The ranking by this method may possibly modify the order denoted by the average in Table II.

To what extent there is likelihood of any effect upon the order of rank by this step may be judged upon analyses of the basis of the decision for each part of intervals as recorded in Series C. In this series the group worked for a unanimous verdict on what constituted the deciding criterion, just as it worked for a unanimous verdict on the order. The final decisions of the group are contained in Table IV.

TABLE IV—*Basis of judgment for individual pairs*

	$c' g'^b$	$c' d'^b$	c′ f′	c′ d′	c′ e′	$c' e'^b$	c′ g′	c′ c″	$c' a'^b$	c′ b′	c′ a′
$c' d'^b$	s										
c′ f′	b	s									
c′ d′	s	s	s								
c′ e′	b	s	p	s							
$c' e'^b$	b	s	p	s	p						
c′ g′	b	s	b	s	s	s					
c′ c″	b	s	b	s	p	p	b				
$c' a'^b$	s	s	b	s	b	s	b	b			
c′ b′	b	s	b	b	b	b	b	b	b		
c′ a′	s	s	s	s	s	s	b	b	s	b	
$c' b'^b$	b	s	b	s	b	b	b	b	s	b	s

b—blending; p—purity; s—smoothness. The order of the intervals in this table is the order used in giving the test.

Table IV shows that thirty-one of the pairs are determined primarily by the factor of blending, thirty-one primarily by the factor of smoothness, and only in four pairs does purity enter in as the determining factor. In the comparisons of the dissonant intervals c′d′ and $c'd'^b$ with the remaining intervals the element of roughness is the characteristic that determines the judgment in every case, except in the pair c′b′ and c′d′. c′c″ and c′a′ depend primarily upon the criterion of blending. In the comparison with c′e′ and c′c″, purity enters as the deciding factor. In comparison of c′a′ with these two intervals, smoothness gives c′a′ the first place. The ranking of c′a′ is largely determined by the criterion of smoothness. However, in the judgments of the pairs c′a′ and c′b′, and c′a′ and $c'b'^{b}$, blending becomes the criterion. c′e′ is determined by blending in its comparisons with $c'b'^{b}$, c′f′, $c'a'^{b}$, c′b′, $c'b'^{b}$. In the judgment of the difference of major and minor thirds, purity is the most distinct element which gives c′e′ the better rank. c′f′ in all cases not mentioned above, except in the case of $c'e'^{b}$, is judged on the blending factor. In the case of $c'e'^{b}$ the purity of the two intervals determine their rank, as c′f′ ranks II in purity while $c'e'^{b}$ ranks III. The minor sixth ranked above the minor third on account of its relatively greater degree of smoothness. In all other cases, not mentioned above, the minor third is judged on the basis of blending. c′b′ is judged on its lack of the factor of blending in all cases, except in its comparison with $c'd'^{b}$. In the two dissonances c′b′ c′d′, there is difficulty in deciding on account of their apparent difference in character. Both are extremely dissonant, c′b′ ranking lower in blending and c′d′, on the other hand, ranking perceptibly lower in smoothness. As the blending is the more important factor, c′d′ is given the first place. In the pair $c'b'^{b}$ and $c'a'^{b}$, there is a minimal difference in blending, but $c'a'^{b}$ is perceptibly smoother than $c'g'^{b}$. In the intervals $c'g'^{b}$ and $c'b'^{b}$ blending determines the judgment. In some cases, such as c′c″ and c′a′, all three criteria coöperate. The superior ability to perceive consonance consists in selecting the factor which most influences the ranking.

Turning then to the specific question before us, we may estimate, on the basis of data in Table IV, what the probable effect would be of a single decision according to the above directions as compared with an average decision for these three criteria.

The analysis is reduced to final figures in Table V in which "average preference" is taken from the last column in Table II for piano and tuning forks respectively;—B., S. and P. denote the number of times the judgment was based upon the factor of blending, smoothness, and purity respectively, for each interval when compared with other intervals according to the exhibit in Table IV.

"Weighted preference" is calculated by weighting the average in accordance with the number of decisions based on each of these factors. Thus, turning to Table IV, we see that for the interval c′g′ the decision may be reached seven times on blending, and four times on smoothness, while purity need not be considered; the preference rank for blending is 10 and for smoothness 9. For this interval, we accordingly get 7x10+4x9 ÷11=9.6 as the weighted average.

Section A, of table V (Fig. 8) is based on the piano quality but as a rough approximation we have used the same weighting for tuning forks, Section B of Table V.

TABLE V.—*Comparison of weighted and average preferences*

A. For Piano

Int.	Av. Pref.	Order	Wt. Pref.	Order	B.	S.	P.
c′ c″	11.0	I	11.0	I	6	2	2
c′ g′	9.3	II	9.6	II	7	4	
c′ a′	7.7	III	9.0	III	3	8	
c′ e′	7.0	IV	7.5	IV	5	4	2
c′ f′	7.0	V	6.9	V	7	3	1
c′ a′^{b}	6.0	VI	5.9	VI	5	6	
c′ e′^{b}	5.0	VII	5.0	VII	3	5	3
c′ g′^{b}	3.7	VIII	4.0	VIII	7	4	
c′ b′^{b}	3.3	IX	3.0	IX	7	4	
c′ d′	1.7	X	1.1	X	1	10	
c′ b′	1.3	XI	1.1	XI	10	1	
c′ d′^{b}	0.0	XII	0.0	XII		11	

B. For Tuning Fork

Int.	Av. Pref.	Order	Wt. Pref.	Order
c′ c″	11.0	I	11.0	I
c′ g′	9.7	II	9.6	II
c′ a′	8.3	III	8.3	III
c′ e′	6.7	V	8.0	V
c′ f′	7.0	IV	8.1	IV
c′ a′^{b}	6.3	VI	6.5	VI
c′ e′^{b}	3.7	VIII	3.5	VIII
c′ g′^{b}	4.0	VII	4.4	VII
c′ b′^{b}	3.3	IX	3.4	IX
c′ d′	1.3	XI	1.1	X
c′ b′	1.7	X	1.1	XI
c′ d′^{b}	0.0	XII	0.0	XII

It is rather surprising that for the piano the weighting does not alter the order found for the mere average. For the purpose of a tentative working norm with the piano, tempered scale, (when the decision is made on one of the three factors directed as above, namely: if possible, on blending; if not, on smoothness; and if not on either of these two, on purity), the order in which the intervals are given in Tables II, III, and V may be regarded as the standard order from the best consonance to the worst dissonance, as expressed in Fig. 9.

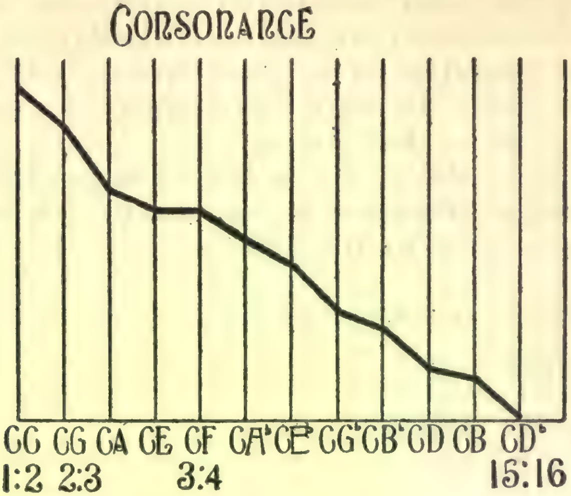

FIG. 9. Norm: the order of consonance-dissonance for the piano.

A rough approximation to the relative degree of certainty in the preference of one interval to another is shown by the numbers which denote the number of times an interval is preferred. This is true both for great differences, *e.g.*, c′c″ and c′d′, as well as for adjacent intervals, *e.g.*, c′c″ and c′g′. The irregularities in the curve, of course, mean just such differences; thus, in Fig. 9 the difference between the consonance of c′c″ and c′g′ is decidedly larger than the difference between c′e′ and c′f′.

Since the primary object of this investigation was to standardize the measurement of the sense of consonance, the main object of the present section of the work was to secure a norm which might be considered a conventional standard for such purposes. All this work on ranking is, therefore, merely accessory to the main object of this investigation. For this reason, the detailed discussion of the introspections and the theoretical interpretation of the empirical records may perhaps best be deferred for a more elaborate investigation.

We have here, at least, a tentative norm established for the first time after recognition of the principal factors isolated under experimental control. Later refinements of experiments may make minor changes in the order, but we have made progress by developing a working principle—the recognition of specific criteria.

MEASUREMENTS OF THE PERCEPTION OF CONSONANCE AS A MUSICAL TALENT

Having determined the constant factors of consonance, the ranking order of the intervals, and the method and apparatus adapted to this test, the writer will in this section, give an account of measurements made under the above prescribed conditions. These measurements were made with three ends in view: first, to secure measurements of individual abilities; second, to establish a norm; and third, to test this measurement under controlled conditions.

Apparatus

The intervals of the octave c′c″ were presented by the method of paired comparison, being played on a piano accurately tuned in the tempered scale. The tones were sounded with moderate loudness, the soft pedal being applied continuously during the test. Each two-clang was sounded with a duration of approximately 2 seconds, with an interval of 1 second between the members of each "pair", and 4 seconds between each repetition. Every pair was sounded at least twice, more frequently three or four times, and in the more difficult comparisons a relatively greater number of times.

Definition and illustration of criteria

Special precautions were taken to impress the fact that mere agreeableness is not the basis of the decision. It was pointed out that a dissonance may be very agreeable for some musical purposes and that the rich musical body of the two-clang, such as the major third, may be the most agreeable and still not the most consonant. It was made clear that the test is a cognitive act of discrimination as opposed to the traditional affective test employed in music.

A placard bearing the definition of consonance was placed before the class, reading as follows:

Consonance is:

(1) *Blending,* a seeming to agree, to belong together.

(2) *Smoothness,* relative freedom from beats.

(3) *Purity,* thinness of tone, absence of richness.

The conductor of the test then explained tersely and concretely how the experiment would proceed, how to record, and how to apply the above-defined criteria in arriving at a decision. The 66 trials, which constitute one complete set, were made in one hour. The intervals used to illustrate the above criteria were sounded in a different octave from the one used in the test. Both the negative and positive aspects of the criteria, *i.e.,* consonance and relative absence of consonance were presented. Thus, without naming the intervals, c′c″—c′b′ and c′e′—c′b′ were given to illustrate blending, the first interval in each pair bringing out the positive, the second, the negative aspect of blending. As illustrations of smoothness, the pairs c′b′—c′d′ and c′a′—c′e′♭ were played. In both of these pairs judgment is best based on smoothness, the first presenting a large difference, the second a small difference. The element of roughness in the minor third is scarcely perceptible, but it is the deciding factor in the comparison of these two intervals, as the major sixth undoubtedly owes its higher rank to its greater degree of smoothness in this pair. c′c″—c′e′♭ were selected to illustrate tonal purity. The octave is a relatively pure interval, while the minor third is rich in quality. In order to give a still clearer conception of purity, a criterion somewhat vague in the mind of the average observer, a tuning-fork was sounded before an attuned Helmholtz resonator, which gave a clear pure tone; and this was compared with the rich tone of the piano and violin and with two-clangs. The observers were finally instructed to make their judgments on each pair with respect to the three criteria in the order named and illustrated; namely, giving first preference to blending, second to smoothness, and third to purity. In all cases where they found blending to be the decisive factor, they were instructed to judge on this criterion. In case they were unable to decide on the basis of blending, they should take the second criterion into account; and, if smoothness was not decisive, the test of purity should be applied. In a large portion of the cases the three criteria coöperated and agreed.

Since the sequence of intervals is a factor that cannot be overlooked, a fixed order of comparisons, which distributed the consonances and dissonances fairly was adopted, as given in Table VI. The body of this table contains three sets of information:

TABLE VI—*The order of trials, the correct preference and the schedule of demerits*

	$c'g'^b$	$c'd'^b$	$c'f'$	$c'd'$	$c'e'$	$c'e'^b$	$c'g'$	$c'a'^b$	$c'b'$	$c'a'$	
$c'd'^b$	1 1 4										
$c'f'$	2 2 3	3 2 7									
$c'd'$	22 1 2	4 2 2	5 1 5								
$c'e'$	23 2 4	24 2 8	6 2 1	7 2 6							
$c'e'^b$	39 2 1	25 2 5	26 1 2	8 2 3	9 1 3						
$c'g'$	40 2 6	41 2 10	27 2 3	28 2 3	10 2 2	11 2 5					
$c'c''$	52 2 7	42 2 11	43 2 4	29 2 9	30 2 3	12 2 6	13 2 1				
$c'a'^b$	53 2 2	54 2 6	44 1 1	45 2 4	31 1 2	32 2 1	14 1 4	15 1 5			
$c'b'$	61 1 3	55 2 1	56 1 6	46 1 1	47 1 7	33 1 4	34 1 9	16 1 10	17 1 5		
$c'a'$	62 2 5	63 2 9	57 2 2	58 2 7	48 2 1	49 2 4	35 1 1	36 1 2	18 2 3	19 2 8	
$c'b'^b$	66 1 1	64 2 3	65 1 4	59 2 1	60 1 5	50 1 2	51 1 7	37 1 8	38 1 3	20 2 2	21 1 6

For each block the top number denotes the order of the trial; the first number below denotes whether the first (top heading) or the second (side heading) is the better; the third number denotes the number of demerits assigned.

In each square the *first* figure denotes the order of trials, the *second* the correct preference, and the *third* the amount of demerits (to be explained later), in case of error in the preference.

The sequence of trials is the conventional order in a series of paired comparisons: each two-clang is named by reading the name at the top and the name at the side in two columns that intersect and form a given square. The two-clang given at the top of a column was always sounded first and the one at the side second. The observer was required to express his preference 1 or 2 according as he preferred the first or the second.

The evaluation of the record is based on the ranking of the intervals established in the preceding part, Table II.

The weighting of demerits

In order to arrive at a method of grading the records, an arbitrary scale of demerits was established. The amount of the demerit for each incorrect judgment was computed on the deviation from the norm. One unit of demerit was given for each step of deviation from the norm. Thus, the observer, in his judgment of the pair c′c″-c′g′ signified by recording 2 that the latter interval is the better consonance, he was given a demerit of 1, as c′g′ is in rank removed 1 step from c′c″. If, on the other hand, in his judgment of the pair c′c″-c′e′♭, he records his choice as 2, thereby placing the minor third as a better consonance than the octave, the error is more significant, and he is given a demerit of 5. The greatest possible demerit for any one judgment is 11 as in the pair c′c″-c′d′♭.

If every answer should be wrong there would be 286 demerits according to Table VI. But this cannot happen because in the long run fifty per cent. of the judgments would be correct by chance, since there are only two possibilities in each case. This reduces the maximum number of probable demerits to 143, which would be the number for one who had *no ability* to appreciate differences in consonance and dissonance and depended entirely upon chance. Such demerit, therefore, is equivalent to 100 ÷ 143, or seven-tenths of one per cent. The records may then be stated in terms of per cent. of success in conforming to the norm by deducting .7 per cent. from 100 per cent. for each demerit earned. While this weighting is somewhat arbitrary, it does approximate justice to the situation because it is approximately proportional to the magnitude of the error in each case.

Since it would complicate matters to require the observer to follow the order of Table VI in recording, the records were kept in straight columns, the first three containing twenty records each and the fourth six,—one column being left blank between each of these to give space for the marking of error and demerit.

This test was first made on the students in the elementary psychology class in the University of Iowa for the class of '12-'13. After this research had been completed the department furnished similar records for the '13-'14 class; the following year Miss Nesta Williams furnished the records for the '14-'15 class; and Mrs. Esther Allen Gaw contributed the records for the class of '15-'16. Since the publication of the original document has been delayed it is possible to incorporate this large mass of data which have been gathered through the very generous coöperation of the members of the department of Psychology, into one group making 1045 cases.

The norm established.—The general distribution of these cases is shown in Fig. 10, which is based on a number of cases sufficiently large taken as a norm. In other words, this curve serves two purposes: it shows how abilities in this act vary and distribute themselves; and it may serve as a norm in terms of which any future record may be interpreted.

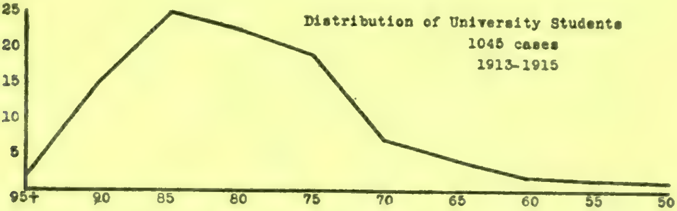

FIG. 10.

Bearing on the order of ranking—The data contained in Part

II bear in themselves a basis for the ranking of intervals which may serve at least as a basis for the criticism of the norm established before. The records for the class of '12-'13 are tabulated to show the total number of preferences for each interval. These are shown in Table VII. In the first column the intervals are given in the order accepted as a norm. (Fig. 9, Table V). The second column contains the per cent. of cases in which each interval was preferred over all with which it was compared. From this the rank of the intervals is indicated in column 3 which shows the deviation of this empirical ranking from the norm.

TABLE VII—*The rank of the intervals in the 1913 class test*

	% of choices	Rank of choices
$c' c''$	12.4	2
$c' g'$	10.0	5
$c' a'$	11.8	3
$c' e'$	13.1	1
$c' f'$	9.6	6 or 7
$c' a'^{b}$	9.6	6 or 7
$c' e'^{b}$	10.5	4
$c' g'^{b}$	9.8	8
$c' b'^{b}$	6.5	9
$c' d'$	3.8	10
$c' b'$	2.1	11
$c' d'^{b}$	1.8	12

A glance at this table shows rather satisfactory agreement between the standard order and the empirical order. The orders VIII, IX, X, XI, and XII are the same in both cases, and with these may be counted VI and VII which happen to tie. The deviations occur, therefore, in the first five intervals, chiefly, *i.e.,* in the consonances; and it will be observed that these deviations are due mainly to the fact that the major third is unduly preferred in the empirical rankings. This can be accounted for by the fact that the factor of agreeableness had not been eliminated satisfactorily in the test of this first year. The musical value of the third as compared with the octave must have influenced the students to some extent so that there was a large number of cases in which the major third was preferred to the octave and the fifth. The dropping of the major third in rank will of course raise the octave and the fifth and secure closer agreement with the norm. The same principle is perhaps also operative in tending to throw the middle range somewhat higher than the norm. The intervals $c'e'^{b}$ and $c'g'^{b}$ and $c'b'^{b}$ are rich musical intervals which may have been favored slightly on the same fallacy as that which threw the third off.

It will probably be found that this sort of error was eliminated by more rigid instructions on this point, emphasizing the fact that the preference is an intellectual judgment rather than an appreciation of musical value in the terms of agreeableness.

With this one exception then, the empirical results on the whole tend to confirm the order established in the norm.

The class of '12-13 was required to fill out a questionnaire on musical training in the form given by Professor Seashore in the report of the Committee on "The Standardization of Pitch Discrimination" (25). This questionnaire is designed to secure a measure of general musical ability, musical training, musical environment, and the expression of musical feelings. For the present purposes, the members of the group were ranked on musical training. The Spearman co-efficient R between this musical training and the record for the consonance test is only $R = .02$, which is very remarkable in view of the fact that one should ordinarily expect those who had had musical training to do better than those who had had none. This absence of correlation is of the greatest significance for the value of this test in that it tends to show that it is fairly independent of training and will, therefore, have diagnostic value.

The correlation between perception of consonance and ability to perform, *i.e.,* to sing or play in music is based upon the same questionnaire returns, gave the Spearman coefficient of $R = .06$ which again is an indication of the effect that the perception of consonance is quite independent of training because it would be fair to assume that the degree of correlation would easily be covered up by the principle of selection by which those who have a good ear for consonance would be likely to acquire musical training.

The correlation between pitch discrimination and the perception of consonance by the Pearson product-moments method was found to be r = .18. This is not so large a correlation as one should really expect and it may be that this is due partly to the fact that pitch discrimination is an immediate sensory experience, whereas the perception of consonance as here tested involves a complex judgment.

The Pearson coefficient for the correlation for consonance and tonal memory is .34 which speaks for the close relationship of these two factors.

Evaluation of the method.—Roughly, the goal of this series of experiments has been reached; we have found a norm for the order of consonances and dissonances and a norm for the distribution of abilities among university students. Both of the fields here opened up must be worked more fully and the two problems are quite distinct. In connection with these experiments, much material has been collected and much is inherent in the records themselves which would throw light on the validity and interpretation of these norms as well as upon the technique of measurement.

But some place must be set for the division of labor; and, since Mrs. Esther Allen Gaw and others have taken up the experimental work in the laboratory from the point at which it was left by the writer in 1914 and propose to carry the analysis of this measurement into finer details, this report must come to a close with the apology that it is only preliminary.

Recommendations Toward a Standard Test

The method of procedure that has been followed, as stated above, can be recommended in giving a test in the perception of consonance, but it is necessary to emphasize certain precautions that must be followed.

In giving the interval, the experimenter must exercise care in the striking of the two keys so as to make the tones equally strong, for the factor of intensity plays a rôle in consonance. The experimenter should practise the combinations and order of pairs until he can play them with ease and without hesitation in an approximately uniform manner.

As has been pointed out by *Seashore* (25), "the tone most favorable for accurate results" is one of moderate intensity, "the just perfectly, clearly perceptible tone." "It is ordinarily purer than a stronger tone and favors concentration." This precaution in the measurement of pitch discrimination applies as well to the measurement of the perception of consonance. The piano tone is rich and tends to develop many impurities when sounded loudly. These are partially at least if not wholly eliminated through the use of the soft pedal.

Uniformity of duration is important, as the sounding of one tone or note of the two-clang longer than the other proves a distraction and disturbs the observer in his discrimination. It also gives him a clue as to the interval played and changes the nature of the test. The longer duration of one note of the pair tends to change the character of the interval as this note takes a dominant place in the perception, and thus influences the judgment.

The two clangs within the pair should be presented in rapid succession with a constant interval of 1 second, as discrimination of successive stimuli involves the element of memory. A brief interval, therefore, presents the best condition for comparison as "the curve for tonal memory shows that the accuracy of memory falls off very rapidly, immediately after the first second of the interval." (25). A longer interval is necessary between the pairs to eliminate the influence of progression of intervals. Each pair should stand distinctly by itself as a stimulus for comparison and should have no reference to the preceding or succeeding pair. An interval of four seconds accomplishes this end.

The order of presentation of the pairs should be definitely determined by the preparation of a key in which the consonances and dissonances are distributed throughout. This order should also distribute the easy and difficult comparisons, so that the test will be somewhat uniform in difficulty of discrimination throughout sections of the whole test. Such an order prevents undue fatigue at any one point in the test as it conforms in some measure to the double fatigue order, which is a rule of of experimentation in psychological tests. The order also prevents the succession of two-clangs in a definite harmonic series, which must be avoided in the test.

The key given above Table VI was prepared with these precautions in mind, and is well adapted to the measurement of the perception of consonance. If the pairs are to be given in the reverse order, a different key should be made and given separately. The order should not be reversed in the repetitions, as this causes confusion and leads to mistakes in recording.

It has been noted how the element of fatigue may, to some extent, be obviated by the arrangement of the order of presentation. A test of this nature is naturally interesting if conducted in the correct manner, and elicits a continuous conscious effort, which becomes fatiguing if prolonged beyond the endurance of those tested. As has been pointed out by Seashore (25), this fatigue is not a fatigue of the sensory process, but it arises from the concentration of the attention. The attention tends to fluctuate and become distracted when engaged in continuous concentration for any length of time. This is more the case, the greater the conscious effort needed to make an intelligent choice or judgment. The perception of consonance requires this concentration to a very great degree, as it is relatively complex in its nature and requires a keen discrimination and constant application to perceive differences. In this respect, it differs from the mere sensory tests which involve only one factor. As an additional precaution against ennui, or to prevent fatigue, a rest is allowed after each group of ten trials. This divides the one hour recitation time during which the test is given, into three periods, of which the last two, when the element of fatigue is liable to be prevalent, are somewhat shorter than the first period. This tends to equalize the conscious effort, and prevents incorrect judgments due to fatigue.

What has been stated above applies to the sustaining of the attention. In order to secure the attention of the observer, a further precaution is taken in securing the right attitude toward the test, that will stimulate the conscientious application. The experimenter, in giving a class test, must have the energetic and enthusiastic coöperation of all participants. This cannot be overemphasized as an important factor in the measurement of the perception of consonance, which requires such a careful and discriminating application of attention to the details involved.

Summary of Conclusions

Among the conclusions reached in this study the following are prominent:

1. The historical failure to reach an agreement in regard to the rank of consonance and dissonance is due largely to a disagreement as to what constitutes consonance.

2. The perception of consonance is a cognitive process, involving the factors of blending, smoothness, and purity.

3. The order of the ranking of the intervals varies for different qualities of tone. The order has been established for tuning forks, piano, and pipe organ.

4. The uniformity of the distribution curves for different classes tends to show that the factors of the test can be controlled so as to make it well adapted as a class test.

5. A system of weighting errors has been established.

6. The distribution of grades reveals a very great diversity in this capacity among normal observers.

7. The perception of consonance is elemental in a secondary sense in so far as it is based rather on the elemental capacities for pitch discrimination and tonal memory than on acquired musical ability or training.

8. The test in itself is not an adequate measure of musical capacity, but forms one of a series including pitch discrimination, tonal memory, sense of rhythm, tonal imagery, etc. that may be advantageously used for this purpose.

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A REVISION OF THE CONSONANCE TEST

BY

ESTHER ALLEN GAW

The consonance test as described by Malmberg in the foregoing article[1] yielded excellent results, but Professor Seashore and Dr. Malmberg both saw the possibility and need of further refinement of procedure. The writer has continued the experimental study of the problem and wishes to report here certain revisions, notably: the elimination of undesirable intervals, the elimination of the system of demerits, and the simplifying of the definition and concept of consonance. A preliminary norm for children has also been established.

After giving the test in the fall of 1915, the records of the three hundred and eight sophomores enrolled in elementary psychology in the University were analyzed for the purpose of determining how the actual order of preference by those tested compared with the norm, what intervals were exceptionally easy or exceptionally difficult and what constant tendencies to error might be discovered.

In Fig. 1, the sixty-six comparisons are so arranged as to show for each comparison first, the number of demerits assigned (heavy solid curve); second, the per cent. of mistakes (broken curve); and, third, the weighted record (dotted curve). The vertical scales for these three curves are respectively, one demerit for each space in the first, ten per cent. of mistakes for each space in the second, and one hundred weighted demerits in the third, the three scales being designated A, B, and C respectively.

The first curve, then, shows simply how many demerits were assigned to a mistake for each pair. The second shows the per cent. of mistakes for each pair. Since there were three hundred and eight cases and each person made one judgment for each pair, the per cent. of mistakes is found by dividing the number of mistakes for a given pair by 308. And the weighted demerits

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[1] Malmberg, C. F. The perception of consonance and dissonance (in this Volume).

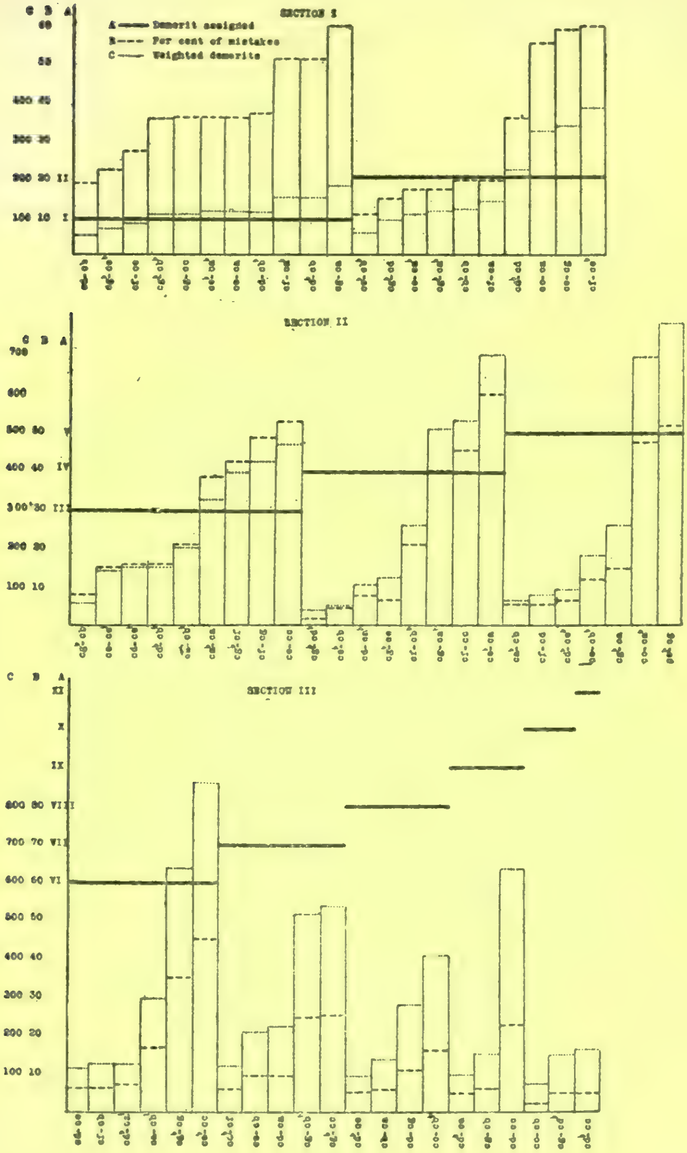
SECTION I
A —— Demerit assigned
B - - - Per cent of mistakes
C —— Weighted demerits
C B A
60
50
400 40
300 30
200 20 II
100 10 I
SECTION II
C B A
700
600
500 50 V
400 40 IV
300 30 III
200 20
100 10
SECTION III
C B A
XI
X
IX
800 80 VIII
700 70 VII
600 60 VI
500 50
400 40
300 30
200 20
100 10

FIG. 1

of curve c denote the number of mistakes for each pair multiplied by the demerit assigned to that pair.

The curve is divided into three sections merely for the convenience of placing on the page; it should be regarded as continuous.

It will be seen in the curve that, in each group of pairs for each demerit, there are some pairs that show a relatively low and others a relatively high number of mistakes. If we isolate these we shall probably find that these group themselves according to some principle, or principles, which may explain the respective tendencies. For this purpose we may take from those that receive the highest number of mistakes, three for each of groups 1-4 two from each of groups 5-7; and one from each of groups 8 and 9. A corresponding number from each group of those that show the smallest number of mistakes may represent the other extreme.

In examining these we discover certain motives which operate to increase the number of mistakes, if they work in opposition to the difference that is to be perceived, and to reduce the number of mistakes, if they tend to increase the difference. The former may be said to operate negatively, the latter positively.

A. *Richness of clang quality.* By this is meant the relatively rich, complex, and pleasing quality of certain clangs in contrast to the pure, thin, and, in some respects, harmonically less desirable clang quality of other equally good consonances or semi-consonances. Thus, while the octave is the best consonance, the major third is given that rank in these tests. Here there is a conflict between a relatively pure consonance and one relatively rich, because mediocre and poor observers are influenced by this richness in one of the members of a pair.

Throughout our series, then, if a relatively pure and thin clang is to be preferred to a relatively rich clang, that will lead to a corresponding increase in the number of mistakes; whereas, if the clang which is to be preferred is relatively rich and the other relatively pure, that will lead to a corresponding decrease in the number of mistakes. In the former case, this motive operates negatively; in the latter, positively.

B. *Similarity of dissonance or semi-dissonance quality.* It is easier to compare two dissonances of the same kind such as c′d′-c′d′$^{\flat}$ than to compare two dissonances of different kinds such as c′d′-cb$^{\flat}$, regardless of their order of rank, because it is easier to compare two things of the same kind than two things of different kinds. Like motive A, this may operate either negatively or positively. If the comparison is between dissonances of different kinds, it will increase the number of mistakes, whereas if it is a comparison of dissonances of the same kind, it will tend to lessen the mistakes.

While, from one point of view, this is a motive for constant error, it is, from another point of view, a condition for an actual difference, either positive or negative. That is, it makes certain comparisons actually easier or more difficult (according as it acts negatively or positively) than the difference in rank in the norm would indicate.

C. *Conspicuous roughness.* Roughness in the dissonances is by far the easiest mark of dissonance. c′d′, *e.g.*, is always conspicuous for its roughness; and, wherever that interval is involved, it is relatively easier to detect it than to detect a dissonance of the c′b′ type. This again may operate either positively or negatively. If the poorer clang is c′d′, this motive acts positively and makes the judgment easier; whereas, if c′d′ is the better clang, it acts negatively and makes the decision more difficult.

Like motive B this is also a condition of actual difference in the ease or the difficulty of recognizing a given interval in which it operates. In that respect motives B and C differ from motive A, which is merely a motive for constant error; they are also conditions of actual difference.

The cases grouped under these motives are really merely illustrative, because not only are there more instances in which two motives coöperate, but it is a practical certainty that there are numerous cases in which two or more motives conflict and result in an interference which reduces or eliminates the net error. There are also many cases in which more than two motives for constant error are present. Those mentioned are, however, probably the most important, because they go far to account for the deviation of the empirical order from the true order of rank.

There are undoubtedly other motives present, but for a rough preliminary analysis, we may arrange the intervals which were excessively high or excessively low in mistakes, as indicated in Fig. 1, under the negative or positive aspect respectively of each of these three motives as follows:

After each interval is indicated the per cent. of mistakes of each pair.

A. *Richness of tone quality*

Negative

Excessive Mistakes

$c'\,g'-c'\,a'$	(60)
$c'\,f'-c'\,e'^{b}$	(60)
$c'\,e'-c'\,g'$	(56)
$c'\,c''-c'\,a'$	(53)
$c'\,e'-c'\,c''$	(50)
$c'\,g'-c'\,f'$	(47)
$c'\,e'^{b}-c'\,a'$	(57)
$c'\,f'-c'\,c''$	(43)
$c'\,g'-c'\,a'^{b}$	(40)
$c'\,g'-c'\,e'^{b}$	(50)
$c'\,c''-c'\,a^{b}$	(45)
$c'\,e'^{b}-c'\,c''$	(46)
$c'\,g'^{b}-c'\,c''$	(25)
$c'\,g'-c'\,b'^{b}$	(24)
$c'\,c''-c'\,d'$	(22)
$c'\,f'-c'\,a'^{b}$	(49)
$c'\,f'-c'\,g'$	(45)
$c'\,c''-c'\,b'^{b}$	(16)

Positive

Minimum number mistakes

$c'\,g'^{b}-c'\,e'^{b}$	(22)
$c'\,e'^{b}-c'\,b'^{b}$	(11)
$c'\,g'^{b}-c'\,b'$	(7)
$c'\,a'^{b}-c'\,b'$	(4)
$c'\,e'^{b}-c'\,b'$	(5)
$c'\,f'-c'\,b'$	(6)
$c'\,e'-c'\,b'$	(9)

B. *Similarity in tone quality*

Negative

Excessive mistakes

$c'\,d'^{b}-c'\,b'$	(51)
$c'\,g'^{b}-c'\,g'$	(34)

Positive

Minimum number mistakes

$c'\,e'-c'\,a'^{b}$	(17)
$c'\,e'-c'\,e'^{b}$	(15)

C. *Roughness*

Positive

Minimum number mistakes

$c'\,d'-c'\,b'$	(19)

A-C *Musical Quality and Roughness*

Positive

Minimum number mistakes

$c'\,g'^{b}-c'\,d'$	(15)
$c'\,g'^{b}-c'\,d'^{b}$	(4)
$c'\,e'-c'\,d'$	(6)
$c'\,d'^{b}-c'\,e'$	(4)
$c'\,f'-c'\,d'^{b}$	(6)
$c'\,a'-c'\,d'^{b}$	(4)

If we examine the curves showing the demerit assigned (heavy solid curve, Fig. 1) and the result of weighting the demerits for each pair (dotted curve, Fig. 1) we find that the actual order of difficulty is not inversely proportional to the distance in the order of rank, as is assumed in the system of demerits. This is due primarily to the constant errors which have been noted, of which the chief one is the tendency to be influenced by motive A, musical agreeableness. But, as was pointed out above, motives B and C are also causes or conditions of *actual clearness of difference*. The norm is based on the actual order of consonance-dissonance. These notions will, therefore, operate to make the empirical order of rank legitimately different from that of the norm, because it makes certain pair-differences either more or less clearly perceptible.

Malmberg found that the empirical rank in 1913 did not correspond to the norm. The same was found for these records of 1915 which were taken by the same method. A comparison of the two deviations from the norm is shown in Table I, which gives, first, the order of rank in the norm as established by Malmberg; second, the empirical order as determined by the per cent. of choices in the 1913 records; and, third, the empirical order of rank as established on the basis of the per cent. of choices in 1915 records.

TABLE I

Malmberg norm		*Empirical order of 1912-13*		*Empirical order of 1915*	
		Rank	% of Choices	Rank	% of Choices
1	$c'\,c''$	2	12.4	3	11.4
2	$c'\,g'$	5	10.0	7	10.1
3	$c'\,a'$	3	11.8	2	12.2
4	$c'\,e'$	1	13.1	1	12.7
5	$c'\,f'$	6 or 7	9.6	4	10.8
6	$c'\,a'^{b}$	6 or 7	9.6	6	10.5
7	$c'e'^{b}$	4	10.5	5	10.7
8	$c'\,g'^{b}$	8	8.8	8	6.7
9	$c'\,b'^{b}$	9	6.5	9	5.8
10	$c'\,d'$	10	3.8	10	4.1
11	$c'\,b'$	11	2.1	12	2.0
12	$c'\,d'^{b}$	12	1.8	11	2.1

In this table it will be observed that the principal deviation is among the consonances, but extends somewhat downward through the semi-consonances,—whereas the dissonances and one semi-consonance maintain their rank according to the norm, except for a very slight reversal of the last two in 1915, which is negligible. In these deviations from the norm we notice the same general principle that was designated above as motive A, to the effect that there is a tendency to give undue preference to the musically rich and harmonically desirable intervals and that, therefore, the relatively pure and thin consonances are forced down in rank. Thus, the octave is forced down to rank two in one group and rank three in the other. The perfect fifth is forced clear down to the fifth rank in one group and to the seventh rank in the other; but the sixth maintains its rank in one group and is raised one point in the other.

The major third shows the most notable change in that it is given first rank in both groups. The fourth practically maintains its balance, falling slightly in one group and rising slightly in the other. The minor sixth maintains its rank, and the minor third is raised three points in rank in one group and two in the other. That is, the most notable advances are the major third and the minor third which are both conspicuous for the very rich tone quality of the two-clang, and the most notable drop is that of the fifth and octave which, though pure, lack that very richness which gives preference to the ranks immediately below.

The greatest source of error in the test is, then, the failure to adhere rigidly to the definition of consonance by allowing musical agreeableness to play a rôle in the decisions. This factor must, therefore, be further controlled in future tests.

The analysis thus far then has shown that, if the system of weighting is to be continued, it should be readjusted empirically on the basis of records in which the above motives for constant error have been eliminated in so far as possible. To this problem we shall return later.

The analysis has also shown that certain intervals are undesirable either because too easy or too difficult, as the result of the operation of causes for constant error. The natural remedy for that is to eliminate these, and limit the material to those pairs for which these sources of error are relatively absent.

In order to reduce the number of factors to the minimum and to give the widest range of choice from the material available, it was decided to select only eleven pairs—one for each degree of difficulty as represented by the original system of demerits, which is based on the order of rank in the consonance-dissonance norm. There is manifestly a great advantage in using a small number of pairs, other things being equal, because these may then be examined in fuller detail and be better controlled, aside from the fact that they are the best from the larger group of the original test.

The following points were kept in mind (a) Each interval in the octave shall appear at least once. (b) Since Malmberg's order differs from the customary order in harmony in the case of the intervals, c′a′ and c′f′, no pairs shall be chosen which would be affected by that reversal. (c) Since it is very difficult to judge an interval on the criterion of purity alone, and, since the tendency is to judge a rich clang better than a pure clang, because it is more pleasing, all comparisons which rest primarily upon the criterion of purity, or richness, according to Malmberg's classification of the criteria (Table VI) shall be avoided. For example, we do not use the comparison c′c″-c′e′ nor c′g′-c′a′. (d) In addition to the above four restrictions, the extremely difficult and the extremely easy comparisons, according to the showing in Fig. 1, shall be eliminated where consistent with the observance of the other restrictions. (e) These shall be comparisons of consonances with consonances, semi-consonances with semi-consonances, and dissonances with dissonances, and each of these three with each of the other two.

Reference to the Malmberg Table VI, showing the pairs arranged according to demerit, will help in keeping the following choice of intervals clear.

The following is a list of the pairs finally selected, with statement of the reasons for the choice:

Octave and minor second (*c′c″-c′d′*^{b})*—eleven demerits.*

This was the only possible interval with that number of demerits.

Octave and major seventh ($c'c''$-$c'b'^{b}$)*—ten demerits.*

The only other interval with this number of demerits is a comparison of a smooth and pure consonance with a very rough dissonance.

Perfect fifth and major seventh (c′g′-c′b′)—nine demerits.

One of the other possibilities was c′d′-c′c″ which was discarded because of the abnormal number of mistakes. The other possibility, c′ a′-c′ d'^{b}, was discarded because it was a comparison of a pure consonance and a rough dissonance.

Major sixth and major seventh (c′a′-c′b′)—eight demerits.

This seemed the best of the four possibilities, because it is a comparison of a clear consonance with a clear dissonance.

Major sixth and major second (c′a′-c′d′)—seven demerits.

Of the four other possibilities, one contains a very rough dissonance, one contains c′ b′ which we have already used three times, and the other two mixed comparisons are found to be hard to judge.

Perfect fifth and diminished fifth ($c'g'$-$c'g'^{b}$)*—six demerits.*

Four of the other pairs contain c′ e′, c′ e'^{b}, c′ a′, and c′ a'^{b}, respectively, which are so often incorrectly judged on account of their rich and pleasing qualities. The other one possibility contains c′ b′ which cannot be used again. The result is that we have an interval which is relatively more difficult that its rank would indicate.

Major third and minor seventh ($c'e'$-$c'b'^{b}$)*—five demerits.*

There were six other possibilities. Two of these were c′ e'^{b}-c′ g′, and c′ a'^{b}-c′ c″, each of which is a comparison of a very pure consonance with a rich consonance which has been found too hard to judge considering its high demerit. Two others, c′ f′-c′ d′, and c′ g'^{b}-c′ a′, are too much of the type of the six pairs already chosen. The other possibility contains c′b′, which has already been used three times.

Perfect fifth and minor sixth ($c'g'$-$c'a'^{b}$)*—four demerits.*

This is a type of comparison that ought to be included, that of a pure consonance with a rich consonance, and, since the demerit is not too high, it seems best to use this pair here.

Major third and minor third ($c'e'$-$c'e'^{b}$)*—three demerits.*

This is a comparison of two rich consonances, and therefore relatively easy, but c′ a′-c′ a'^{b}, of the same order, would have been a better choice.

Major seventh and minor seventh ($c'b'$-$c'b'^{b}$)*—two demerits.*

This is a comparison of two dissonances, a type which must be included.

Perfect fourth and major third (c′f′-c′e′)—one demerit.

This was chosen in order to include the perfect fourth, but it is really too easy.

To determine in a preliminary way the effect of the use of these eleven pairs alone, the record on these intervals was taken out from the complete record of the sixty-six pairs in the 1915

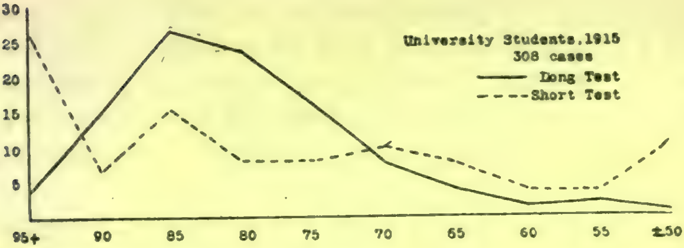

Fig. 2

test. Fig. 2 shows a comparison of the distribution according to the 66 unit test (the original) and the 11 unit test, by the method of weighted demerits. The curve shows that the 11 unit test is very much easier than 66 unit test. This difference in difficulty is, of course, due (1) to the elimination of the extremely difficult pairs, and (2) to the elimination of the principal motives for constant error.

A serious question, therefore, arises as to whether the test in this new form is too easy. It could, of course, be readily changed to any desired degree of difficulty without reintroducing seriously any of the sources of error which have been eliminated, but, in view of the desirability of having the norm for the adults comparable with the norm for children whose records run lower, it was decided to keep the material with the degree of difficulty here found. However, the new method of evaluation introduced below makes the test even with this material more difficult again.

So far the intervals have always been considered as occurring in the key of C. There is a decided advantage in varying the key to avoid the monotony of using the same notes, c′, c″, throughout. And there is no apparent reason why it should not be given in other keys, except perhaps that the tempered scale used on the piano would cause the intervals to have a different consonance value. According to a law developed by Stumpf[2] there should be no difference in the consonance of the various intervals in different keys even in tempered scale.

[2] Stumpf, Carl. Beiträge zur Akustik und Musikwissenschaft, III, Table IX. Leipsic 1898.

But there might be subjective influences which would affect the standing of the intervals in keys other than C. Furthermore, Stumpf did not make as fine distinctions as we are making here. Therefore, it was decided to give the test in the three keys of c, b^b, and g, to determine how they compared. This was done in October, 1916.

To one section of two hundred and twenty-two sophomores the list of eleven pairs was given four times in the key of c, and four times in the key of b^b, and four times in the key of g.

The result is shown graphically in Fig. 3 in terms of the percentage of correct judgments for each pair in each key. As will be seen, the correct judgments are approximately the same for each of the three keys used, which corroborates under any conditions, and to a serviceable degree, the principle laid down by Stumpf.

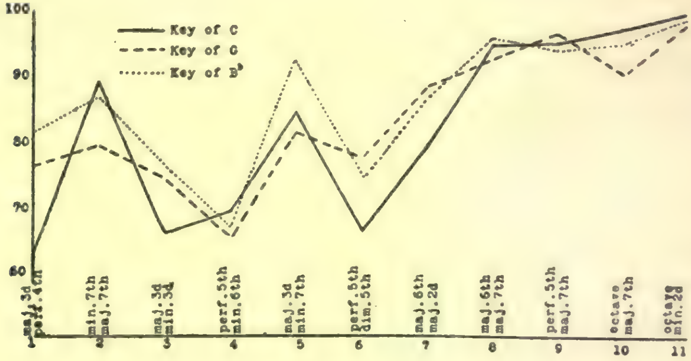

FIG. 3

Fig. 3 also shows certain fluctuations in the degree of difficulty for different pairs, which are strengthened by the fact that they tend to agree for the three different keys. These may be interpreted in the light of the previous discussion.

The selection of the eleven pairs from the 1915 test yielded, of course, only one judgment for each interval, which is too little to be reliable. In a regular test, the pairs must be repeated as many times as possible to get a large number of trials.

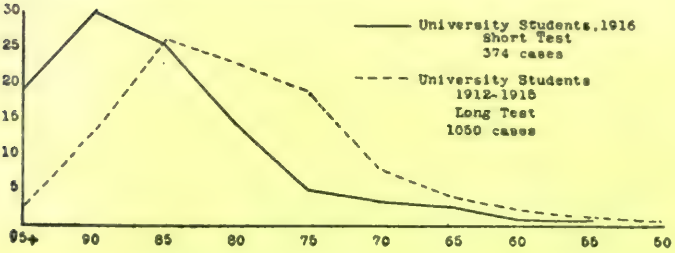

FIG. 4

Fig. 4 shows the distribution of this 1916 group of records as compared with the distribution of Malmberg's 1050 cases in the original form of the test. It will be seen that the difference between these two distributions is analogous to that found in Fig. 2. Fig. 4 is undoubtedly more reliable, because the dotted curve is based upon a larger number of cases, and the solid curve is based upon eighty-eight judgments as compared with eleven in Fig. 2.

If we should regard a selected group of pairs as, *e.g.*, the eleven intervals here selected, each played in three or four keys, as a single unit, it would simplify procedure very much to do away with the system of ranking errors by demerits, and use simply the per cent. of right judgments as a measure of ability. This is, of course, the reciprocal of the number of mistakes.

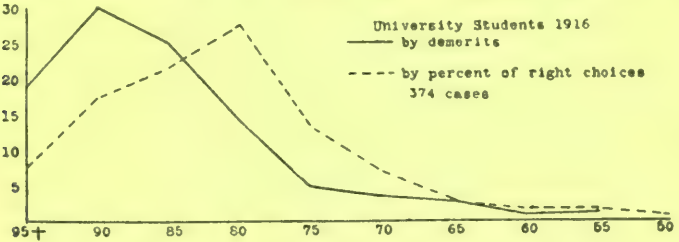

FIG. 5

In Fig. 5, this method is compared with the original method of grading by weighted errors. The disparity between the two curves shows that the method of demerits tends to yield a higher ranking than the method of mistakes, as the latter curve falls below at the better end, it rises correspondingly at the poorer end. This may not indicate any disparity; indeed, it points to an advantage in that the distribution by the former method made the test a trifle too easy.

The main question to consider is whether or not the order of ranking is disturbed seriously by the difference in tabulation. The Spearman coefficient for the correlation of rank between the two methods for the three hundred and seventy-four cases of University students is R = .99, p.e., .02. This correlation is higher than the actual facts would indicate. But the Spearman coefficient of rank between the two methods for one hundred and ninety-nine seventh and eighth grade children is R = .89. p.e., .03. Since the correlation is very good in both cases we unhesitatingly adopt the new and simpler procedure for future use.

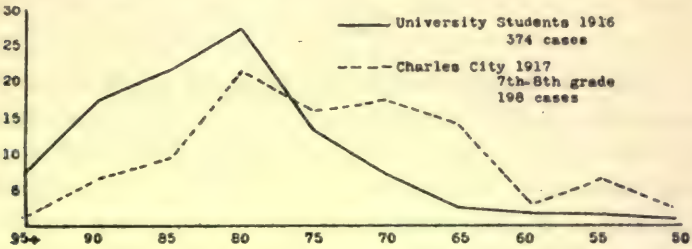

FIG. 6

To make instructions simple and specific, the following definitions were written on the blackboard:

A good combination (of two tones) is one which is *smooth,* in which the two tones *blend,* and seem to *agree* and *fuse together* into one.

A bad combination (of two tones) is one which is *rough,* in which the two tones do not *blend,* and do not *seem* to *agree nor fuse together* into one.

Thus far all our efforts to establish norms have been limited to records of adults. All records taken on children have been evaluated temporarily in terms of the adult norms. We are at present engaged in establishing norms for children. Merely as a preliminary suggestion of what changes may be expected for children we may use here the records of a group of one hundred and ninety-nine children, which comprise all the children in the seventh and eighth grades in the public schools of Charles City, Iowa.

The comparison of the distribution for these children with the distribution for adults is shown in Fig. 6, in which the curves are based upon the per cent. of correct judgments irrespective of demerits. Here is then a clear-cut picture of the ability of children of this age as compared with adults.

The following table is a comparison of the percentile rank of adults and children according to the per cent. of correct judgments. The first and second columns give the per cent. of correct judgments which an adult and a child respectively would have to make in order to get the percentile rank set opposite in the third column. It will be seen that in order to be average in the perception of consonance, or to get a percentile rank of 50, an adult needs to make 70% of correct judgments, while a seventh or eighth grade child must make 54% of correct judgments.

Adult	*Child*	*% Rank*
100	97	100
86	79	90
82	69	80
77	66	70
75	60	60
70	54	50
66	48	40
61	43	30
54	33	20
46	21	10
9	0	0

The establishment of norms for children and their evaluation for different ages represents a large task in the midst of which we are now engaged. In view of the strenuous nature of the test, one must be impressed with the relatively small difference between the achievement of adults and children. This fact becomes even more impressive upon examination of individual evidences. Thus, many of the children make as good a record as the best of the adults, and the disparity between the showing of children and adults comes largely from the incompetency of the comparatively dull children.

THE COMPARATIVE SENSITIVENESS OF BLIND AND SEEING PERSONS

BY

CARL E. SEASHORE AND T. L. LING[1]

The blind have unquestioned superiority in their ability to use their touch, hearing, and other senses for guidance. From observation of this, the conclusion is generally drawn that the sensitivity of their sense organs is correspondingly heightened.

"Through years of experience in the laboratory, the conviction has gradually grown upon me that a more radical distinction should be made between sensitiveness and ability to use a sense; *i.e.,* between inborn sensory capacity and acquired ability or skill. From time to time I have taken the opportunity of comparing my own sensitiveness in touch and hearing with that of blind persons distinguished for ability in guiding themselves by hearing and touch; and in no case did I find that the blind persons possessed any significant superiority to myself in sensitiveness to touch and hearing, although some of the blind persons experimented upon were noted for their wonderful performances through hearing and touch."[2]

We finally found an opportunity to put the matter to an accurate and crucial test. Sixteen blind students from the Iowa College for the Blind at Vinton, Iowa, and fifteen pupils from the Iowa City High School were selected as cases for comparison. The ages of the blind ranged from sixteen to twenty-six and of the seeing from fourteen to nineteen. In selecting the blind, only those were chosen who had been totally blind for more than five years, who were generally otherwise both mentally and physically sound, and were now in high school grades. This resulted in the selection of the ablest pupils in the school. The seeing pupils were taken at random, being selected by the principal on the ground of convenience of schedule. On each of these the following six measurements were made.

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[1] The writers acknowledge their great obligation to Superintendent Eaton for courtesies and coöperation at the School for the Blind and to Dr. Mabel C. Williams for taking responsible part in the making of the measurements, and taking the case histories of the blind children.

[2] Seashore, Carl E., Elemental Tests in Psychology, *J. of Educ. Psychol.,* 1916, 7, 81.

List of tests

1. *Localization of sound.*—Discrimination for the direction of sound was measured in terms of the angular displacement in the horizontal plane directly in front of the observer. A click in a telephone receiver served as stimulus. The receiver was mounted at one end of a two-meter bar which was pivoted at the middle and carried a pointer running over a scale of degrees at the other end. This apparatus was mounted at such distance in front of the observer that the receiver moved at the distance of one meter from the center of the head. The click was produced by the rapid make and break of the circuit through the mercury key. This whole arrangement proved very accurate and convenient, inasmuch as the angular displacement at this point and in this direction is very small. After a preliminary determination of the threshold one hundred trials were made by the method of constant stimuli.

2. *Discrimination for the intensity of sound.*—This was measured by determining whether the second of two consecutive tones which differed in intensity only, was stronger or weaker than the first. The tones were produced by a one hundred vibration electro-magnetic fork in circuit with the audiometer[3]. A standard current of 1.2 volts was used and No. 30 on the audiometer was taken as the basal unit, the compared tones being either stronger or weaker. This provides a tone clearly audible and yet not unpleasantly strong. The records were kept in terms of the units of the audiometer, which represent approximately equal psycho-physic steps. After preliminary determination of the threshold, one hundred trials were given by the method of constant stimuli.

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[3] Seashore, New Psychological Apparatus, *Iowa Studies,* Vol. II, pp. 153-163.

3. *Discrimination for lifted weights.*—A set of bottles forty millimeters in diameter and ninety-five millimeters high was arranged as follows: 3 standards at 80 grams each and 12 compared weights yielding a series—81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 92, and 95 grams. The observers were blindfolded and the standard weights were changed in order to eliminate the temperature error. The weights were arranged with ample space on a small revolving table so that any desired weight could be swung into position without noise. After the preliminary determination of the threshold, one hundred trials were made by the method of constant stimuli.

4. *Discrimination for passive pressure.*—A modified form of the Stratton pressure balance[4] was used. This was built of aluminum which was lighter and therefore more sensitive than the original. By this form of the apparatus it was possible to increase or decrease the standard pressure instantaneously without the slightest jar. The standard pressure was five grams upon the outer side of the third phalanx of the first finger. The pressure location of this was changed slightly for successive trials and the least perceptible increase or decrease in weight was determined, one hundred trials being made by the method of constant stimuli after the preliminary threshold had been determined.

5. *Discrimination for active pressure.*—This was measured by determining under how many thicknesses of paper the position of a wire hair could be located by active exploration with the tip of the first finger. The apparatus consisted of a plate glass disc 10 cm. in diameter, mounted so as to revolve freely. In place of the hair a copper wire, No. 38 B & S, which is about the diameter of the average human hair, was stretched across the plate glass and with ends firmly fastened. Discs of paper cut from Old Veda Bond 17 x 22, twenty pounds to the ream, were placed over this wire, and the blindfolded observer was required to locate the direction of the wire through touch. Starting with ten sheets, five sheets were added for each trial until

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[4] Stratton, Über die Wahrnehmung von Druckänderungen bei verschiedenen Geschwindigkeiten, *Philos. Stud.,* Vol. 12, 1896, pp. 525-586.

a failure occurred; then a single sheet was taken off or added until the greatest thickness through which the wire could be located had been determined. The record is therefore given in terms of the number of sheets of paper covering the wire. To one who has not performed this test, the actual results will seem to be very wonderful achievements, as the records show.

In this test much depends upon economic procedure in the hunting. The observers were therefore carefully taught how to proceed: *e.g.,* to run tip of finger from left to right and, if the wire was not found in that stroke, to run it in a line at right angles to the first; the wire being found by such economic procedure, it was comparatively easy to trace it. If it was not found in the first two strokes, these cardinal movements were continued until the observer acknowledged failure.

6. *Tactual space.*—This consists in the determination of the two-piont threshold in the transverse direction on the tip of the first finger and in the transverse direction on the inside of the forearm, 5 cm. above the wrist.

It is unfortunate that no more than one hundred trials could be made in each of these tests, where the method of constant stimuli was employed, but it must be remembered that much time, more than was required for the actual measurement, was spent in making preliminary determination and securing adaptation which is necessary for tests of this sort. Indeed the elemental character of the tests often hinges largely on full knowledge of all factors involved and skill in preparing the observer so as to eliminate sources of subjective and objective variables.

Case histories: 1. The blind

Case 1. Age, 16, female. Blindness began three days after birth. Can only distinguish light from darkness. Attractive, bright, quick, responsive, and breathlessly attentive, but easily fatigued; reads point with either hand at conversational rate; likes typewriting, plays the piano well, and sings; can hem by hand but does not use a sewing machine; taste and smell are good; has no difficulty in finding her own way on the premises.

Case 2. Age, 26, female, single. Cause of blindness *iridocyclitis;* trouble came on gradually from ten to nineteen. Can tell where windows are in a room; healthy and cheerful, but slow; responsive and tried hard in the tests;

reads point slowly with right hand and follows with left; studied typewriting for a while but dropped it; can sew by hand or machine, crochet, knit, tie, and do housework; has learned basketry, weaving, and broom making; has studied piano two years; taste and smell good.

Case 3. Age, 25, male, single. *Congenital cataract.* Can tell light from darkness; taste and smell good; relies much on hearing; is of a nervous temperament, unattractive, but quiet; critical and sure of himself; reads point slowly with left index finger; uses typewriter, studied piano nine years; profession, piano tuning; also makes brooms, ties, and weaves.

Case 4. Age, 19, female. Blindness due to *leucoma adherens* from *blennorrhea neonatorum;* commenced shortly after birth; can locate windows with left eye; can sort laundry by smell; makes much use of hearing; was fidgety and sighed frequently during the test; bright and alert; reads point rapidly with both hands; plays piano well; sews either by hand or machine; skillful in basketry and fancy work.

Case 5. Age, 23, female, single. Blindness due to *sympathetic ophthalmia;* ran a knife into her right eye when a child and failed to get proper treatment; can tell daylight from darkness with her left eye; goes about alone in usual places but never on the street; reads point with both hands at conversational rate; sews, ties, crochets, etc.; tries to do all kinds of house work; plays the piano well; fine young woman, neat and pleasing, quiet manner.

Case 6. Age, 18, male. Blindness due to *phthisis bulbi* from *blennorrhea neonatorum;* pleasing appearance, alert, attractive, but fatigues readily; reads point with left index finger at conversational rate and anticipates with right; uses typewriter well; is musical and sings well; guides himself in the environment without difficulty.

Case 7. Age, 19, male. Blindness due to *phthisis bulbi.* Stuck a shoe awl into right eye when nine years old and rapidly lost sight of both eyes a year later. Guides himself in environment with skill and ease; taste and smell good; basket weaving, broom making; carpet weaving; reads point slowly with left index finger; plays piano and violin a little; likes typewriting.

Case 8. Age, 19, male. Blindness due to chronic *conjunctivitis;* began when six months old. Can locate windows and see the light of the sun but not the sphere itself; taste and smell good; cheerful, reliant, and mentally probably a little above the average; reads point; tunes piano; takes typewriter apart just for the fun of it; has a work shop and whole set of tools at home; built a house seven feet square twenty feet up in a tree two years ago.

Case 9. Age, 19, female. *Atrophy of optic nerves* due to accident at age of fourteen. Intelligent and responsive and tried hard in the tests; uses typewriter; is skillful in basketry and fancy work.

Case 10. Age, 17, male. Blindness due to chronic *iridocyclitis* caused by *spinal meningitis* at six months. Lost sight suddenly at age of twelve; taste and smell good; reads point with either hand at conversational rate; can work in the garden, but not hoe; makes baskets and hammocks.

Case 11. Age 19, female. Blindness due to *sympathetic ophthalmia;* ran scissors into left eye when four years old; right eye failed gradually. Can see light, locate windows, and avoid obstacles; ordinary intelligence; reads point with left index finger at conversational rate but not with right hand at all; plays the piano; uses typewriter, sews, and does fancy work.

Case 12. Age, 19, male. Blindness due to *maculae corneae from blennorrhea neonatorum.* Goes about the city alone; learns new towns quickly; conscious of using hearing extensively; responsive and attentive; boastful; reads point well; plays pipe organ, piano, and violin; gives concerts.

Case 13. Age, 20, female. Blindness due to *congenital atrophy* of optic nerves. Taste and smell good, but does not use them much; good orientation; nervous; reads point with right index finger, left following; uses typewriter, sews, and does fancy work.

Case 14. Age, 21, female. Blindness due to *phthisis bulbi* from *blennorrhea neonatorum.* Can detect light with the left eye; reads point and braille with either hand but faster with the right; plays piano and sings well; sews and does fancy work, and house work.

Case 15. Age, 25, female, single. Blindness due to *phthisis bulbi* from *blennorrhea neonatorum.* Cannot detect light; taste and smell good; responsive, good application; reads braille better than point; sews and does fancy work and light house work.

Case 16. Age, 20, female. Blindness due to *phthisis bulbi* from *blennorrhea neonatorum.* Can detect light and sometimes colors and outlines of persons; bright, very attentive; reads point with right index finger rapidly and is considered one of the best; uses typewriter, plays piano, and pipe organ, sews, and does house work.

2. *The seeing*

Case 1. Age, 18, male, junior. A good student.
Case 2. Age, 14, male, freshman. A medium student.
Case 3. Age, 17, female, junior. A medium student.
Case 4. Age, 16, male, freshman. A medium student.
Case 5. Age, 21, male, senior. A superior student.
Case 6. Age, 17, male, freshman. A medium student.
Case 7. Age, 17, male, freshman. A medium student.
Case 8. Age, 19, female, junior. A good student.
Case 9. Age, 18, female, senior. A very bright student.
Case 10. Age, 17, male, senior. A medium student.
Case 11. Age, 18, male, senior. A medium student.
Case 12. Age, 18, female, senior. A medium student.
Case 13. Age, 15, male, sophomore. A medium student.
Case 14. Age, 15, male, freshman. A very poor student.
Case 15. Age, 15, male, sophomore. A good student.

TABLE I—*The blind*

Cases	Localization of Sound	Intensity of Sound	Lifted Weight	Pressure	Touch	Tactual Finger	Space Arm
	Degrees	*Units*	*Grams*	*Grams*	*Sheets*	*m. m.*	*m. m.*
1	1.4	1.5	3.1	.64	25	1.5	20
2	3.0	2.0	5.6	.32	32	1.8	
3	5.2	.5	4.0	.63	31	1.3	51
4	1.4	1.3	3.2	.18	21	1.6	30
5	1.3	1.4	4.8	.66	35	1.5	35
6	1.8	.8	4.3	.46	30	1.1	21
7	2.1	2.0		.34	30	.6	27
8	2.0	.8	2.5	1.31	35	1.0	12
9	4.8	1.4	5.2	.66	29	1.1	47
10	2.0	.7	3.0	.38	10	.9	20
11	2.1	1.8	6.6	.38	25	.8	5
12	1.3	.7	1.7	.35	38	1.3	24
13	1.4	1.1	4.0	.22	19	2.3	20
14	1.2	1.2		.51	18	1.3	16
15	1.6	.9	4.0	.70	15	.8	30
16	1.6	.8	4.0	.25	20	2.0	24
Median	*1.6*	*.9*	*4.0*	*.38*	*25*	*1.1*	*24*
Ave..	*2.1*	*1.2*	*4.3*	*.50*	*26*	*1.3*	*25*
M.V.	*.8*	*.4*	*.9*	*.20*	*6.7*	*.4*	*8.6*

TABLE II—*The seeing*

Cases	Localization of Sound	Intensity of Sound	Lifted Weight	Pressure	Touch	Tactual Finger	Space Arm
	Degrees	*Units*	*Grams*	*Grams*	*Sheets*	*m. m.*	*m. m.*
1	1.5	1.0	2.9	.13	41	.6	26
2	4.4	1.6	5.2	.98	14	2.1	19
3	2.0	1.0	2.4	.87	18	1.0	35
4	2.2	1.0	4.6	.50	28	1.7	38
5	2.2	.7	3.0	.35	40	1.6	33
6	1.4	1.6	3.3	.72	47	1.2	26
7	2.8	1.1	4.0	.44	36	1.1	46
8	1.9	.9	2.2	.58	35	2.1	22
9	2.7	1.0	4.1	.80	30	1.6	18
10	1.6	.5	4.2	.40	21	2.0	35
11	1.9	.5	3.1	.73	32	1.0	11
12	1.6	1.2	4.4	.54	45	1.6	23
13	.5	.3	1.7	.43	25	.2	10
14	4.0	1.5	3.1	.44	21	2.0	18
15	2.9	2.2	4.4	.23	20	.5	25
Median	*2.0*	*1.0*	*3.3*	*.44*	*28*	*1.2*	*23*
Ave.	*2.2*	*1.1*	*3.5*	*.54*	*30*	*1.3*	*25*
M.V.	*.7*	*.4*	*.8*	*.18*	*8.6*	*.52*	*7*

Statement of the results

Localization of sound.—In this test the blind are slightly superior to the seeing, especially in terms of the median. The blind vary more than the seeing, the coefficient of variability being 33 and 48 for the blind and the seeing respectively. The records of the former range from 1.2 to 5.2 degrees while the latter vary from .5 to 4.4. The finest record of all was made by a seeing person.

The intensity of sound.—In this test the blind are slightly superior to the seeing according to the median but inferior by the same amount according to the average. The coefficient of variability is practically the same, namely, 32 for the blind and 33 for the seeing. Here again the best record of all is made by a seeing person, the same one, No. 13, who made the best record in localization of sound.

Lifted weights.—In this test the blind are inferior to the seeing both according to the median and the average. The coefficient of variability is approximately the same, 23 for the blind and 24 for the seeing. Here the finest record made is the same for the blind as for the seeing. But there are more extremely poor records among the blind than among the seeing.

Pressure.—In this test the blind are somewhat superior to the seeing both according to the median and the average. The blind are more variable, the coefficient being 40 for the blind and 33 for the seeing. The records of the blind range from .18 to 1.31 and those of the seeing from .13 to .98.

Touch.—In this test the larger the number the better the record. The facts therefore show that the blind are inferior to the seeing both according to the median and the average. There is but slight difference in the variability although the seeing have four records that are better than the best record of the blind.

Tactual space on the finger.—In this test there is no significant difference in the median and the average. But the variability of the seeing is greater, the coefficient being 40 for the seeing and 27 for the blind. The seeing have two records that are better than the best of the blind.

Tactual space on the arm.—Here again there is no significant difference in the median and the average nor in the coefficient of variability.

The general conclusion then so far as the net results of the facts are concerned must be this, that, while there are slight differences shown in the Tables, there is no *significant* constant tendency in the records to favor either the blind or the seeing. In other words, *the blind and the seeing under these circumstances are, on the whole, equally sensitive to the direction of sound, intensity of sound, lifted weight, passive pressure, active pressure, and tactual space.*

Interpretation of these findings

These experiments were planned on the assumption that the tests would be elemental; *i.e.,* that the measurements were so simple and natural that training, experience, and special skill would not affect the results. In other words we aimed to test native capacity as distinguished from acquired ability.

From one point of view we may say, therefore, that the outcome of this series of experiments is to prove that the specific tests here used are elemental, because the records do not favor those who have acquired very marked skill and efficiency in these senses. That itself is an important feat in experimental procedure, because it sets up a new standard for psycho-physic tests. Records of psychological and psycho-pedagogical experiments for the past twenty-five years are full of examples showing how capacities like those here mentioned improve with age, intelligence, and practice. If the above conclusion is right we must re-submit those findings to determine to what extent the improvement found was due to the maladaptation of the experiment and the lack of skill of the experimenter rather than to characteristic change in the persons measured.

We cannot too strongly emphasize the necessity of reducing the procedure in an experiment of this kind to its simplest terms so that the record shall be of the actual capacity rather than of the possession of skill in adjusting oneself to a complex situation. There are scores of pitfalls in each one of the above experiments, which, if allowed to enter uncontrolled, would detract from the elemental nature of the test.

If we regard the results then from the converse side, they prove that the extraordinary skill in guidance through hearing and pressure and other senses in the blind has its basis in apperception rather than in sensation or in the direct and immediate judgment of difference. The person who reads the point print has learned to give meaning to sensory impressions which the seeing person tends to neglect although possessed of the same power as the blind in sensing these differences.

If, then, we say that the blind person who reads point print, almost as we read with our eyes, and guides himself through hearing in many respects almost as we guide ourselves with our eyes, and we regard these performances as representative of the thousands and thousands of situations which occur in life, we arrive at the conclusion that the seeing have countless wonderful capacities lying latent and unrecognized so far as conscious use is concerned. The apparent squandering of sensory capacities may well be compared with the great waste in the struggle for existence by various forms of prolific extravagance in reproduction. We are very richly endowed with capacities of which we employ only relatively few, and these in a very inadequate way. The achievements of Helen Keller, *e.g.,* illustrate this.

But after all, it is difficult to appreciate the full extent to which we actually do depend upon the sort of fine sensitiveness here measured. While most of us do not read with our finger tips or guide ourselves with our ears when walking, we do make constant use of these senses in ordinary activities, most of it unconsciously. It may, therefore, be said, from one point of view that, that while seeing persons are not trained in certain specific acts of skill, they are trained in the use of the sensibilities involved in such skill. Indeed we are born with hierarchies of blind "instinctive skill". We often appeal from the sense of sight to touch and we constantly respond to the environment through hearing without resort to the physical mechanism in terms of which we think.

Technically all these tests involved discrimination as distinguished from sensitiveness or sensibility. The sensory judgment is reduced to its lowest terms and is not far different from perception in its immediacy.

The conclusions of these experiments may then be summed up in the following statements:

First. The blind who are skillful in the use of touch, muscle sense, and hearing are not more sensitive or keen in sensory discrimination than seeing persons when fundamental capacities are tested.

Second. The necessity of making our psycho-physical tests elemental is strikingly indicated by the results of these tests.

Third. Development of the use of a sense consists not in the heightening of sensitivity or sensory discrimination but in the development of complexes and meanings in terms of these.

THE ELEMENTAL CHARACTER OF SENSORY DISCRIMINATION

BY

CARL E. SEASHORE AND KWEI TAN

The problem here reported grew out of that of the preceding article by Seashore and Ling in which it was demonstrated that the blind, though so largely guided by the sense of hearing and touch in their daily activities, are not superior to seeing persons in elemental tests of fundamental capacities in these senses. In that investigation an elemental test was defined as one in which the "measurements were so simple and natural that training, experience, and special skill would not affect the results." This fact of the equality of the blind and the seeing was regarded as proof of the elemental character of the test.

To gather proof from another angle it was decided to take one of these tests, namely, discrimination for the intensity of sound, and submit a number of observers to prolonged practice for the purpose of determining whether or not ability in this test improved with practice. The procedure was exactly the same as reported in the preceding article. The audiometer was used with the 100 v.d. fork, the current being kept at 1.2 volts. The mercury was kept clean, and the physical conditions and the control of the instrument were satisfactory throughout. A single increment was employed for the whole series, namely, the step from 38 to 39, on the audiometer, and the test consisted of one hundred trials for each day under conditions as nearly constant as possible, both subjective and objective. The record was kept in terms of the number of right cases. The observers, designated by letter in the following table, were all students in Psychology who had had some experience in experimental work but no training in this particular test.

In a few cases two or even three hundred trials were taken during the same day, but the general effort was to get one set of observations a week. The experiments were conducted in the light-sound-and-jar-proof room in the psychological laboratory with both observer and experimenter present in the room. The room was ventilated freely every twenty minutes

Records of these trials are shown in Table 1, in which the numbers given are the number of right decisions in each one hundred trials for each of the chosen observers. The average and median are given only for thirteen periods. It is evident that it would not be fair to continue the average beyond that point for the reason that each observer represented a different degree of ability and the dropping out of, *e.g.*, D. and H. W. at the end of the thirteenth day would distort the average record seriously.

The fluctuation in these figures may appear at first as being rather large, but when one considers that the record is in terms of right and wrong cases, there is really a very satisfactory uniformity on the whole.

Records of introspections and objective observations were kept faithfully, but as these are of an ordinary nature it is hardly worth space to detail them here. Suffice it to say that the variations in the per cent. of right cases is not greater than one would ordinarily find in a single one hundred trials on successive days under very favorable circumstances in any type of discrimination.

TABLE I—*The effect of practice on discrimination for the intensity of sound*

	A.	F.	H.	T.	G.W.	N.W.	C.	D.	Go.	Gr.	H.W.	*Median*	*Ave.*
1.	88	91	94	89	86	65	88	76	86	95	74	88.1	84.7
2.	90	92	92	89	88	64	95	75	88	94	65	89.0	84.7
3.	94	97	92	83	91	69	89	78	90	90	77	89.7	86.3
4.	93	95	80	78	91	87	97	86	80	93	79	87.3	87.1
5.	92	78	76	68	91	89	95	83	89	92	76	88.0	84.4
6.	91	80	73	72	87	89	90	68	94	88	82	86.5	83.0
7.	94	99	75	89	79	87	98	69	89	98	89	90.8	87.8
8.	92	99	90	94	88	91	95	82	94	96	76	91.5	90.6
9.	92	88	93	92	83	89	99	78	89	93	63	90.0	87.1
10.	88	90	95	95	94	85	88	82	82	86	69	87.0	86.7
11.	86	94	91	93	98	75	97	81	83	76	71	84.5	85.9
12.	87	91	78	85	100	79	90	82	87	91	61	86.0	84.6
13.	95	91	89	82	95	79	91	84	85	85	59	86.4	85.0
14.	87	96	84	93	95	90	89		93				
15.	89	96	99	85	94	75	90		80				
16.	88	96	94	96	91	84	90						
17.	90	93	96	95	85	90	93						
18.	83	86	94	91	94	86							
19.	95	96	97	94	96	93							
20.	84	96	96	67	92	90							

Looking then at the average and the median, we see that these run practically constant for the thirteen days. Beyond the thirteenth day each observer's record must be judged by itself, and it will be found that in these there is no marked tendency toward raising or lowering the general average for a given observer. We must, therefore, arrive at the conclusion that, for periods of training represented by this series, there is in this test no marked evidence of improvement with practice. For a single observer one hundred trials are inadequate, by the present method, but by taking a larger number of observers under similar conditions and by treating the results together in the average and the median, we compensate in part for this shortcoming.

Some of the fluctuations must, however, be accounted for by recognizing a certain degree of complexity in the problem. For example, various observers reported from time to time that they observed, or were trying, accessory aids in judging; for example, the sound was visualized and the judgment was made in terms of distance, the fainter sound being farther away. Or the difference was imaged in terms of motor tendencies, the lower sound calling forth, in one type, less effort because it was easy to hear and, in another type, the larger effort as a matter of counteraction. On the whole the introspections do not reveal any case in which the adoption of a particular method seems to have changed capacity permanently from the point of adoption.

Furthermore, the situation was not entirely free from objective disturbances. The observations being taken in the sound-light-and-jar-proof room, exceedingly faint accessory stimuli did prove disturbing. In an earlier experiment of this kind, one observer said that he could hear his backbone creak under these circumstances. This was probably not true, but it illustrates the tendency to be affected by obscure stimuli. There are, of course, momentary disturbances of itching, pain, or pressure, due to the holding of the receiver to the ear. Together with this there is also the subjective factor, the change in disposition, physiological tone, aggressiveness, etc. from day to day.

Bearing in mind that this test was selected as a sample from among six other tests which were supposed to be elemental, it is reasonable to conclude, in the absence of evidence to the contrary, that the same elemental character could be established for the other tests reported in the foregoing article.

The only one of these on which there is any considerable amount of reliable literature available is that of lifted weights. This test has, perhaps, been studied with more exactness than any other test in the psycho-physical literature. Extraordinary refinements have been made in the discovery of the conditions for change in the capacity. Most of these are in the nature of the laws of illusions. But, as we look back upon literature as a whole, we find that ordinarily a careful observer does not improve with training. He may and usually does go through a cycle of changes which may be traced to the operation of certain motives for illusion. The same would probably be observed in any psycho-physical test that can be subjected to sufficiently rigorous study.

We have, then, in this and the preceding article evidence of the elemental character of the tests from two points of view, namely, that of highly specialized sense training in actual life, in the blind, and that of accurately controlled measurement of training in a comparatively short series.

There is a third line of evidence that must be sought. In fact, these experiments were suggested by the discovery that in pitch discrimination the actual native capacity in sensory discrimination for pitch does not develop with age. Whether that rule applies to these six tests should be worked out with great care upon a series of ages of children from, say eight to sixteen. On all the tests, we have records of children showing clearly that there is improvement in the record, which we may call the "gross record" or "total output", from year to year up to about fifteen. But the challenge set up by this experiment is to repeat those experiments and analyze them to find out to what extent this improvement with age consists in overcoming the difficulties which are due to the incomplete mastery of the test by the observers. In other words, we may lay down this as an hypothesis for further experiment: In psycho-physic tests of sensitivity or discrimination the conditions must be so simple and so accurately under control that they are equally fair to the skilled and the unskilled, the trained and the untrained, the young and the old. Only then shall we measure sensory discrimination in its true capacity.

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A Higher Scale of Mental Measurement and Its Application to Cases of Insanity

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A HIGHER SCALE OF MENTAL MEASUREMENT AND ITS APPLICATION TO CASES OF INSANITY

By

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One of the great needs of practical psychiatry is that of standardized methods of mental measurement. For some such methods a debt of gratitude is already due to psychologists; but our experience in their application has gradually led us to realize that the standards which have been developed and made available do not take sufficiently into account environmental influences. It has been too readily assumed at times that a difference in the showing of two subjects is necessarily to be attributed to a difference in native mental capacity.

It will be granted, of course, that to provide a satisfactory correction of the error due to the variable influence of environment would be a difficult matter; but it has occurred to us that the difficulty might be materially reduced by confining our proposed tests to a selected sphere of knowledge or activity in relation to a corresponding and more or less readily measurable *sample* of the environment, so to speak, rather than to the environment as a whole.

To take a concrete example, we could, perhaps, form a more useful practical judgment of the aptitudes of a printer's apprentice by considering the speed and accuracy with which he can set up a page of text in relation to the length of his apprenticeship, than we could by applying a series of tests of general intelligence and then attempting to correct the results by somehow taking into account the sum total of his general environmental influences.

Assuming that this is so, then in order to develop a generally applicable method it is necessary, before all, to choose a more or less readily measurable "sample" of environment which would affect at least a majority of possible subjects. We say choose, but the fact is there is hardly any choice in the matter, for only one general environmental element has been in any degree standardized and is at least roughly measurable, namely, the element of systematic education. In spite of some variation of standards in different parts of the country, everyone recognizes a certain degree of general uniformity in magnitudes represented, say, by "four elementary school years," "eight elementary school years," "high school education" or "collegiate education."

In speaking of systematic education as a measurable environmental element, in this connection, we do not mean such vague, though important, parts of it as scholastic atmosphere, refining influences, stimulating associations; these parts, being variable and hardly measurable, must not be allowed to affect the results; we mean only the process of the actual imparting of knowledge, and preferably that knowledge which is more or less basic or theoretical, and not with which one is apt to come in touch in extra-scholastic life.

Having these considerations in mind, our special problem became to develop a simple method whereby a subject's mental capacity might be estimated from a measure of what he has acquired in the course of his education, and from a comparison of his acquisition with the average of a group of subjects of the same amount of education.

Our experience with free association tests[1] has led us to believe that just such a test, applied by means of a specially selected list of stimulus words, would best serve our purpose, owing particularly to the great simplicity of the procedure and to the readiness with which the results may be classified and standardized.

This presentation has been arranged in six parts: I. The

---

[1] Kent and Rosanoff. *A Study of Association in Insanity.* Amer. Journ. of Insanity, July and Oct., 1910.—Eastman and Rosanoff. *Association in Feeble-Minded and Delinquent Children.* Amer. Journ. of Insanity, July, 1912.—Isabel R. and A. J. Rosanoff. *A Study of Association in Children.* Psychol. Review, Jan., 1913.

Basic Standards; II. Norms Representing Various Degrees of Education; III. Certain Selective Influences and Effects of Selection; IV. Measurements Made in Cases of Insanity; V. Evaluation of the Method. Suggestion for Better Standardization; and VI. Summary.

PART I. THE BASIC STANDARDS

In selecting the stimulus words we were guided, in the first place, by the usual curricula of schools, comprising the subjects of arithmetic, grammar, geography, history; algebra, geometry, physiology, literature, civics; trigonometry, physics, chemistry, and biology;—and we were further guided by the aim of revealing in each instance the presence or absence of a familiarity with the school subjects concerned, yet such a familiarity which is not likely to be acquired otherwise than in the course of sytematic education. The following list of words was finally selected:

1. geography
2. participle
3. Waterloo
4. refraction
5. arithmetic
6. botany
7. isomerism
8. Portugal
9. amoeba
10. declension
11. burette
12. physics
13. hyperbole
14. retina
15. coagulation
16. Cervantes
17. franchise
18. subtraction
19. metabolism
20. predicate
21. mollusc
22. inquisition
23. amphibious
24. decimal
25. hydraulic
26. osmosis
27. percentage
28. cerebellum
29. fractions
30. titration
31. carbohydrate
32. duodenum
33. cosecant
34. biology
35. Odyssey
36. vertebrate
37. gravimetric
38. federal
39. morphology
40. hypothenuse
41. Magellan
42. hexameter
43. meteor
44. momentum
45. Cornwallis
46. protozoon
47. syntax
48. distillation
49. pollen
50. peninsula
51. binomial
52. crustacean
53. Bonaparte
54. meridian
55. chlorophyll
56. tetrahedron
57. Madagascar
58. corolla
59. ventral
60. Belgium
61. tangent
62. dorsal
63. colloid
64. equator
65. judiciary
66. synthesis
67. Athens
68. epithelium
69. feudalism
70. coefficient
71. perennial
72. plebeian
73. catalytic
74. embryo
75. spectrum
76. continent
77. spore
78. theorem
79. Himalaya
80. Renaissance
81. quotient
82. oxidation
83. haemoglobin
84. axiom
85. Amazon
86. isosceles
87. cohesion
88. protoplasm
89. centrifugal
90. molecule
91. cotyledon
92. abscissa
93. gravitation
94. galvanic
95. logarithm
96. calyx
97. polarization
98. cephalic
99. proteid
100. kinetic

The first part of our undertaking consisted in making tests on a large number of selected subjects, the records of which were to serve for the construction of basic standards.

In the work of collecting material, we adhered to the following instructions, and we furnished the same to our collaborators.

"The test must be given to subjects individually and not in groups.

"It should be conducted in a quiet place reasonably free from distracting influences.

"The stimulus words are read off in the order in which they are given on the printed form, care being taken to pronounce them correctly, distinctly, and in a sufficiently loud tone of voice. At the subject's request, any stimulus word may be repeated, but its meaning must not be explained or discussed. It may also be spelled at the subject's request if necessary in order to make sure that the word has been correctly conveyed to him.

"The subject must be given unrestricted time to formulate a reaction after a stimulus word has been given, but he must be instructed to give the first word that comes to his mind and not to attempt to choose a most appropriate response. The reaction time is not recorded.

"The subject must be instructed to react each time with one word and not with a sentence or a compound word; he must not react by merely repeating the stimulus word or by giving a different grammatical form of it.

"The subject may say that he is not familiar with a given stimulus word or that he is for some other reason unable to react. The experimenter may then proceed with the next stimulus word after telling the subject that he would come back to the unreacted word later on.

"The subject, in spite of instructions, may react in an unacceptable way, as by giving a sentence or a compound word instead of a single word, or by repeating the stimulus word, or by giving a different grammatical form of it. In such a case the reaction is not put down, but the pertinent instructions are repeated and the next stimulus word is given.

"When all the stimulus words have been given the experimenter must give again those stimulus words to which no responses have been obtained or no acceptable responses. Usually even after thus going over the list a second time there will remain a greater or lesser number of instances of failure of reaction."

In scoring the results of the test we have followed the Kent-Rosanoff method of separating reactions into *common* and *in-*

dividual, without making use of the criteria for more detailed classification which seemed unimportant for our present purposes. On the other hand, it became apparent early in the course of our work that a means of as accurate evaluation as possible of each common reaction was of greater importance here than in the scope of application of the Kent-Rosanoff test.

Theoretically, it may perhaps be assumed that a reaction is of biological value according to the *faithfulness* and *comprehensiveness* with which it represents the actual relationships in nature of the things represented by the stimulus word. Practically, our material reveals these relationships only in so far as they are mirrored in the minds of our subjects.

It would seem, *a priori,* that the frequency with which a reaction to a given stimulus word occurs in a series of test records selected at random should be a more or less accurate measure of the element of faithfulness, for chance is obviously against the repeated presentation by different subjects of any one falsely perceived or imagined relationship.

It would seem also that the element of comprehensiveness, too, should be to some extent measurable by frequency, for undoubtedly the more numerous the points of relationship are between a given pair of stimulus and reaction words and the things represented by them, the more often will these points of relationship determine the production of that particular reaction.

But in this connection another factor appears for consideration, namely, the special experience equipment of the group of subjects from whom the material for the frequency tables is obtained. Our experience with the Kent-Rosanoff test, in which commonplace words in daily use serve as stimulus, did not show this factor to be of any great importance; but the case is different with the present test, as is shown by the contrast in the reactions of two selected groups of subjects to the stimulus words *participle, refraction,* and *amoeba,* given in Table I. The first group is that of our one hundred highest qualified subjects; fifty-three of them are "starred" in Cattell's "American Men of Science," and the remaining forty-seven, though not "starred," are also listed there and in addition occupy professorships in scientific departments of higher institutions of learning. The second group is one also of one hundred subjects, but selected at random and having not more than a high school education,—in most cases much less. Attention is called to differences in reactions not only as to kind but also as to group values.

TABLE 1.

PARTICIPLE	Group 1 values.	Group 2 values.	REFRACTION	Group 1 values.	Group 2 values.	AMOEBA	Group 1 values.	Group 2 values.
verb	28	1	light	35	5	animal	12	2
grammar	17	18	reflection	11	1	protozoa	11	0
noun	15	0	glass	10	0	paramoecium	7	0
past	4	0	index	5	0	protoplasm	7	0
infinitive	3	0	eye	4	0	biology	4	0
adjective	2	0	lens	3	0	jelly	4	0
being	2	0	physics	3	0	proteus	4	0
preposition	2	0	bending	2	0	protozoon	4	1
speech	2	2	diffraction	2	0	zoology	4	0
participate	1	12	eyes	2	0	cell	3	1
part	1	11	microscope	2	0	microscope	3	0
partake	0	3	refractory	0	6	animalcule	2	0
word	0	3	refract	0	5	bacteria	2	0
English	1	2	fraction	0	4	bug	2	0
grain	0	2	reaction	0	4	unicellular	2	0
think	0	2	fractions	0	3	water	2	0
			part	0	3	city	0	3
			arithmetic	0	2	medical	0	3
			break	0	2	name	0	3
			decimal	0	2	place	0	2
			deviation	0	2			
			from	0	2			
			numbers	0	2			
			reflex	0	2			
			retract	0	2			
No reaction	0	18	No reaction	0	20	No reaction	1	57

The table contains only the reactions which have for either group of subjects a value of not less than two per cent. Even more striking differences are indicated in the kind of individual reactions given by the two groups. The subjects of Group 1 gave the following individual reactions to the stimulus word *refraction*: high, ice, minerals, myopia, polariscope, repulsion, Snellen, and transparent; while the subjects of Group 2 gave the following: adding, again, bad, biceps, change, consider, decimals, difference, drawing, example, fracture, friction, knowledge, noisy, parts, rebreak, recoil, reduce, refrain, return, shadow, small, sound, sum, summing, test, and traction.

Aside from the obvious difference in the quality of the individual reactions given by the two groups of subjects, the fact of the far greater number of them given by the second group,—twenty-seven as compared with but eight for the first group,—is of significance, especially in view of the circumstance that there were no instances of failure of reaction in the first group and no less than twenty in the second.

We are thus led to conclude that the values of reactions would be erroneously indicated by frequency tables constructed on the basis of material obtained from subjects selected at random; but a special selection of subjects according to education and scientific attainment would seem to make possible the construction of basic standards sufficiently accurate to serve for practical purposes.

It would seem from this that the nearest approach to a perfect standard should be attainable by securing test records from a large number of "starred men" (including women, of course). The obstacles encountered in the work of gathering such material proved, however, greater than we had anticipated, so that in the end we found ourselves in possession of but fifty-three utilizable "starred" men's test records.[2] As our plan was to construct the basic standards, like those of the Kent-Rosanoff test, with test records from one thousand subjects, we had to use for the most part test records from subjects without the qualifications of "starred" men: persons listed in Cattell's "American Men of Science" but not "starred;" a good many, not listed, but holding professorships or instructorships in higher institutions of learning; persons holding a doctor's or master's degree; and others having at least a full collegiate education.

Having constructed frequency tables with the one thousand test records obtained from thus variously qualified subjects, we found that many of the values indicated were obviously erroneous and some perhaps even fictitious; the following instances have been selected as the more striking among the reactions with an indicated frequency value of not less than 1.0 per cent: *isomerism*—geography (1.2), isotherm (1.5), lines (1.0), sleep (1.4); *amoeba*—botany (1.2); *burette*—barette (4.3), French (1.8), hair (2.3); *Cervantes*—man (2.3); *metabolism*—psychology (1.1); *amphibious*—ambidextrous (1.0); *osmosis*—bones (1.3); *titration*—titanic (1.5); *gravimetric*—metric (1.0); *morphology*—death (4.8), sleep (2.0); *Magellan*—man (1.0); *hexameter*—perimeter (1.6); *protozoon*—geology (2.0); *crustacean*—earth (4.7); *chlorophyll*—medicine (1.3); *ventral*—left (1.1), wind (2.3); *colloid*—celluloid (6.6), collar (2.9); *synthesis*—antithesis (2.8); *catalytic*—catalepsy (1.0), catalepitc (4.3), catastrophe (1.0), fit (2.4), fits (1.3); *spore*—sporadic (1.1), sport (1.0); *cotyledon*—cottolene (1.3); *polarization*—flower (1.0); *cephalic*—disease (1.0), syphilis (1.0). Erroneous or fictitious values of less than 1.0 per cent. are, of course, even more frequently to be found.

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[2] A small number of not utilizable test records have been obtained from both, "starred" men and other subjects; we shall have again occasion to refer to these.

The accuracy of the indicated values is further impaired in the cases of many of the stimulus words by the many failures of reaction; thus for the following stimulus words the failure frequency exceeded 5.0 per cent: *isomerism* (21.4); *burette* (15.4), *Cervantes* (6.5), *metabolism* (5.7), *osmosis* (5.8), *titration* (25.4), *duodenum* (7.2), *gravimetric* (5.3), *corolla* (7.5), *colloid* (14.1), *epithelium* (8.4), *catalytic* (11.1), *haemoglobin* (7.1), *cotyledon* (13.9), *abscissa* (10.7), *cephalic* (14.2).

These circumstances led us to select from amongst our test records one hundred, which had been obtained from our most highly qualified subjects, for the construction of a "high standard" which should serve for a more accurate evaluation of reactions. This group of subjects consisted, as already stated, of fifty-three "starred men" and forty-seven others, also listed in Cattell's "American Men of Science," but not "starred," and holding professorships in scientific departments of higher institutions of learning. The high standard values are given in parentheses in the frequency tables. In comparing the high with the general standard values it is to be borne in mind that the former represent frequencies on the basis of 100, and the latter on the basis of 1000.

That more accurate evaluations are represented by the high than by the general standard may be judged from a mere inspection of the frequency tables; for instance, all the reactions enumerated above as possessing obviously erroneous or fictitious general standard values of not less than 1.0 per cent. are without a high standard value. Moreover, we have scored many test records by means of both, the high and general standards, and comparisons of the results have readily convinced us that the high standard values are more trustworthy, as they do not fail to reveal more fully the contrasts between groups of subjects distinguished according to educational and intellectual qualifications.

The introduction of the high standard establishes a new group of common reactions,—those without a high standard value; that some of these are actually without apparent value or with but insignificant value we have already shown; but such is by no means the case with all of them; on the contrary, it seems quite certain that had we a greater number of test records from subjects such as those of our most highly qualified group for the construction of our high standard, many reactions now without a high standard value would have been assigned one. The following reactions with a general standard value of not less than 1.0 per cent. but without high standard value may be mentioned as instances in point: *geography*—America (1.5); *participle*—word (2.9); *Waterloo*—defeat (1.3), war (1.0); *refraction*—glasses (1.0), optics (1.0), rays (1.0); *arithmetic*—fractions (2.0), problems (1.0), school (2.5); *botany*—leaves (1.1); *amoeba*—dysentery (1.0), life (1.6); *declension*—word (1.2); *physics*—sound (1.5); *hyperbole*—simile (1.6); *coagulation*—clotting (1.5); *Cervantes*—author (1.7); *metabolism*—assimilation (1.0), blood (1.9), medicine (1.2); *inquisition*—France (1.5); *decimal*—numbers (1.5); *hydraulic*—mining (1.1); *osmosis*—dialysis (1.2), egg (2.8), physiology (1.8), plant (1.2); *percentage*—fractions (1.9), hundredths (1.3), proportion (1.0); *cere-*

bellum—physiology (1.4); *fractions*—half (1.6), percentage (1.8), school (1.4); *titration*—acid (1.3); *carbohydrate*—fats (1.8), physiology (1.2), proteid (2.0); *vertebrate*—physiology (1.2); *gravimetric*—measuring (1.0); *federal*—army (1.0), histology (1.4); *hypothenuse*—square (1.3); *Magellan*—circumnavigation (1.3), sea (1.0); *hexameter*—iambic (1.1); *meteor*—falling (1.4), flash (1.1), planet (1.4); *momentum*—power (1.5), train (2.0); *Cornwallis*—defeat (1.1), soldier (1.1); *protozoon*—water (1.1); *syntax*—construction (1.9), English (1.9), Latin (1.2); *distillation*—spirits (1.1); *pollen*—bees (1.6), yellow (1.8); *chlorophyll*—biology (1.2), coloring (1.2); *Madagascar*—land (1.0); *corolla*—petals (1.7); *ventral*—physiology (3.0); *dorsal*—physiology (1.9), spine (1.2); *colloid*—chemical (1.3), physiology (1.1); *Equator*—map (1.1), south (1.4); *synthesis*—logic (1.2); *Athens*—Greek (2.3); *epithelium*—lining (1.0), surface (1.2); *feudalism*—barbarism (1.0), France (1.5), mediaevalism (1.2); *coefficient*—factor (1.4); *perennial*—botany (1.3), years (1.3); *plebeian*—history (1.1), Roman (1.5); *embryo*—chicken (1.3), growth (1.1), seed (2.1); *spore*—bacteriology (1.0), biology (4.7), egg (2.0), fish (1.6), mould (1.1), zoology (1.8); *Himalaya*—height (1.3); *Renaissance*—literature (3.8), mediaeval (1.6); *quotient*—remainder (1.1); *oxidation*—burn (1.2), silver (1.7); *haemoglobin*—medicine (1.0); *axiom*—corollary (1.4), law (1.2); *isosceles*—equilateral (1.1); *protoplasm*—botany (1.0), germ (1.3), matter (1.6), physiology (1.2), zoology (2.1); *centrifugal*—center (3.6), circle (1.2); *molecule*—atoms (1.3), little (1.2); *galvanic*—iron (3.6), physics (2.8); *cephalic*—skull (1.2); *proteid*—fat (2.4); *kinetic*—power (2.7).

These examples show that the high standard is also lacking in accuracy owing to insufficiency in the amount of material which has been used for its construction, but that to some extent at least any resulting error can be counterbalanced by taking into consideration, in scoring test records, the number of common reactions without a high standard value.

Turning to the many individual reactions found in our material, we find that a very considerable proportion among them also are apparently of value and would probably have found places in the frequency tables if we had had more adequate material for their construction. In order to provide at least a partial correction of error in the evaluation of individual reactions we prepared an appendix to the frequency tables like the one prepared for use in connection with the Kent-Rosanoff test.

We are thus enabled by means of the frequency tables and the appendix to distinguish the following categories of reactions:

1. Common with high standard value.
2. Common without high standard value.
3. Doubtful, i.e., to be found in the frequency tables but in a different grammatical form.
4. Individual with value assigned by appendix.
5. Individual without value assigned by appendix.

In scoring test records we have found the following measurements to be of the greatest significance in general: (a) Sum of high standard values; (b) Total number of common reactions; (c) Individuality index; (d) Falure index.

The individuality index and the failure index are calculated for each test record in preference to merely noting the number of individual reactions and of failures of reaction for the reason that the significance of an individual reaction or of a failure of reaction apparently varies according to the stimulus word: the stimulus word *isosceles* evoked 36, and *metabolism* 169, individual reactions from the one thousand subjects whose test records were used for the construction of the frequency tables; similarly, there were no failures of reaction to a number of the stimulus words, such as *Waterloo, botany, subtraction,* etc., and no less than 254 to the word *titration;* the frequency tables show various degrees of transition between these extremes. Accordingly, our calculations of individuality index and failure index are intended to make allowance for this variable tendency of the stimulus words to evoke an individual reaction or a failure of reaction; it seems obvious that the significance of an individual reaction given in response to the word *metabolism* cannot be the same as that of one given in response to the word *isosceles,* also that the significance of failing to react to the word *titration* is not so great as that of failing to react to such a word as *subtraction.*

In connection with the frequency table for each stimulus word is given the *individuality frequency* and the *failure frequency* for that word.

In calculating the individuality index for a given test record we obtain first the average individuality frequency by dividing the sum of the individuality frequencies of all the stimulus words, in response to which the record shows individual reactions, by the total number of individual reactions; the individuality index is then obtained by dividing the total number of individual reactions by the average individuality frequency; we have found it sufficient to carry the calculations to the third decimal place. The formula for the calculation is quite simple:

$$\text{Individuality index} = \frac{n^2}{f}$$

n representing the total number of individual reactions and f the sum of all individuality frequencies.

The failure index is calculated in a similar way:

$$\text{Failure index} = \frac{n_1^2}{f_1}$$

excepting that in this formula n_1 represents the total number of failures of reaction and f_1 the sum of all failure frequencies.

Perhaps another element of inaccuracy in our frequency tables should be mentioned before closing this part of our presentation. It is often incredibly difficult, and in some cases apparently impossible, to limit subjects to one word responses; and it has seemed to us that some of our collaborators have not emphasized this point sufficiently in their instructions to subjects; moreover some of the stimulus words have a greater tendency than others to evoke a two word or a compound word reaction. Test records containing more than five such reactions have been regularly discarded by us, as, it seems hardly necessary to say, it would be impossible to construct standards with reactions not limited to one word. We were, however, compelled in the interest of economy of time and labor to accept some test records containing not over five two word reactions, and some others containing even more but belonging to a special group of reactions which we eventually decided to accept: *geography*—North America (0.6), South America (0.4), United States (1.2); *amoeba*—jelly-fish (0.9); *burette*—cubic-centimeter (0.4), test tube (0.7); *physics*—high school (0.4); *retina*—eye ball (0.4); *Cervantes*—Don Quixote (31.0), Sancho Panza (0.3), wind mill (0.4), wind mills (0.7); *franchise*—street car (2.0), street cars (0.3), woman suffrage (0.3); *subtraction*—minus sign (0.5), taking away (0.4); *mollusc*—shell fish (3.7); *inquisition*—Catholic Church (0.4), middle ages (0.3); *amphibious*—land and water (0.4); *percentage*—one hundred (1.2), per cent (0.5), per cent sign (1.0); *fractions*—one-half (0.4), one-quarter (0.2), one-third (0.1), three-fourths (0.6), three-quarters (0.1), two-thirds (0.4); *vertebrate*—spinal column (0.4); *gravimetric*—metric system (0.8); *federal*—United States (4.1); *hypothenuse*—right angle (1.5); *Magellan*—South America (2.3); *meteor*—falling star (0.3), shooting star (0.5); pollen—*hay fever* (0.5); *peninsula*—Cape Cod (0.6); *crustacean*—shell fish (2.0); *Bonaparte*—Saint Helena (1.3); *tetrahedron*—four-sided (0.7), solid geometry (0.6); *Equator*—Mark Twain (0.4), North Pole (0.4), South America (1.3); *judiciary*—Supreme Court (0.6); *synthesis*—building up (0.4), putting together (1.4), put together (0.3); *feudalism*—middle ages (4.6); *plebeian*—hoi polloi (0.4); *continent*—North America (4.5), South America (0.4), United States (0.3); *Himalaya*—Mount Everest (0.6); *Renaissance*—middle ages (1.4), new birth (0.4); *axiom*—self evident (1.6); *Amazon*—South America (6.0); *cohesion* sticking together (0.7); *proteid*—amino acid (0.5).

That the indicated values of these reactions are to some extent erroneous seems probable from the consideration that many more subjects would surely have given them but for our instruction to react with one word; on the other hand, if all our subjects had adhered closely to this instruction we should have had no two word reactions in the frequency tables and the indicated values of many of the one word responses would thereby have been considerably altered. This applies to the high as well as to the general standard values.

A few foreign words have found their way into the frequency tables (*metabolism*—Stoffwechsel, *protozoon*—Urtiere, *plebeian*—sansculotte, etc.); they should, of course, not have been accepted as reactions.

Proper names of persons are indicated in the tables only by the initial letters, exception being made of historical personages (*Waterloo*—Bluecher, Wellington; *refraction*—Newton; *isomerism*—Pasteur; *Portugal*—Manuel, etc.).

Some few words in the tables seem to be neologisms (*isomerism*—isopometric, mern; *Portugal*—comosh; *declension*—luo; *inquisition*—equisition, exquisition; *amphibious*—ampher, etc.); it is possible that some of these have been incorrectly recorded by the experimenters.

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1. GEOGRAPHY.

Individuality Frequency, 115.

Failure Frequency, 2.

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Alaska	(1)	3
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America		15
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Arizona		1
Asia	(1)	15
Athens		1
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A.		1
Austria		1
Baku		1
B.		1
Belgium		1
book	(6)	103
Boston		3
botany		1
boy		1
Brazil		1
brother		1
Bulgaria		1
California		3
Canada		1
chair		1
changed		1
chart		1
child		2
childhood		1
China		1
circle		1
class		1
coast		1
C.		1
commercial		1
continent	(1)	3
continents		2
cosmos		1
countries	(1)	3
country	(1)	6
county		1
cover		1
curriculum		1
Denmark		1
distance		1
distribution		1
D.		1
drawing		1
earth	(5)	51
east	(1)	1
England	(1)	6
English		1
Europe	(2)	22
Florida		1
France		2
F.		9
geodesy		1
geographical		1
geology	(8)	22
geometry		2
geos	(1)	1
Germany		3
Gibraltar		1
G.		1
globe	(2)	9
grammar		13
graph		1
Greece		1
ground		1
growth		1
G.		1
G.	(1)	1
H.		1
Hellenes		1
hemisphere		1
hills		2
history	(10)	76
home geography		1
house		1
Illinois		1
Indiana		1
Iowa		1
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islands		2
isthmus		1
Italy		3
Java		1
land	(8)	51
lands		1
Latin	(1)	4
lesson		1
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London		1
Madagascar		1
magazine		2
Maine		1
Manhattan		1
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Massachusetts		1
mathematical		1
mathematics	(1)	4
M.		1
M.		1
meterology		1
Mexico		2
monography		1
M.		1
M.		1
mountain		7
mountains		5
N.		1
nation	(1)	2
national		1
neurology		1
New Jersey		1
New York	(1)	2
New Zealand		1
north		1
North America	(2)	6
Nova Scotia		1
ocean	(1)	5
Oregon		1
paleography		1
peninsula	(1)	2
Pennsylvania		2
Peru		1
philosophy		1
photography		1
physical	(3)	12
physics		3
physiography		5
physiology		4
picture	(1)	1
place		3
plains		1
plant	(1)	1
plants		1
politics		1
Portugal		1
primary		1
psychology		1
R.		2
rhyme		1
river		7
rivers		1
road	(1)	1
Roosevelt		1
royal		1
Russia		3
school	(2)	32
science	(1)	7
sea		1
shore		1
sister		1
soil	(1)	1
South America		4
South Carolina		1
space		1
Spain	(1)	5
spell		1
spelling		3
sphere		2
state	(1)	5
S.	(1)	1
stream		1
study		12
S.		1
Switzerland		2
Syria		1
T.	(1)	2
teaching		2
Tennessee		1
territory		1
Texas		1
text-book	(1)	2
travel		4
Turkey		1
United States	(2)	12
vocation		1
war		7
W.		1
water		2
world	(2)	24
write		1
writing		2

2. PARTICIPLE.

Individuality Frequency, 71.

Failure Frequency, 3.

a	(1)	5
ablative		2
acting		1
action		4
adjective	(2)	47
adjunct		1
adverb	(1)	31
agree		1
and		1
apostrophe	(1)	1
arithmetic		2
Armstrong	(1)	1
article		2
assistance		1
atom		1
B.		1
being	(2)	13
bending		1
breaking		1
but		1
clause		2
combination		1
composition		1
conjugation		2
conjunction	(1)	7
connector	(1)	1
dangling		2
decimal		1
declension		1
definition		3
deponent		1
doing	(1)	1
editorials		1
egg		1
ending		1
English	(1)	6
finished		1
5:4		1
form		1
formation		1
fraction		3
gerund	(1)	9
gerundive		1
going	(1)	12
governor		1
grammar	(17)	179
grammar school		1
Greek		1
had		1
hanging		1
having		6
he		1
ignorance		1
impartial		1
in		2
infinitive	(3)	25
ing	(1)	21
I.		1
is		1
join		1
language		9
Latin		9
laughing	(1)	1
lively		1
living		1
lying		1
modifier		2
modifying		1
money		1
municipal		1
New Testament		1
noun	(15)	131
nouns		2
of	(1)	8
parenthesis		1
parse	(1)	2
parsing	(1)	1
parsnip		1
parsnips	(1)	1
part	(1)	8
partaking		1
particeps criminis	(1)	1
participate	(1)	3
particle		2
particular		1
partisan	(1)	5
part of speech		1
party		1
past	(4)	18
perfect		1
phrase	(1)	15
pleasing		1
predicate		2
preposition	(2)	16
present		8
principle		4
pronoun	(1)	18
pupil		1
reading		1
ringing		1
running	(1)	8
sailing	(1)	1
school		3
sentence		5
singing		1
skin		1
small		1
speech	(2)	9
standing		1
subjunctive		1
supplementary		1
syntax		1
tense		3
the	(1)	13
thinking		1
to		8
transitive		1
verb	(28)	195
verbal		1
verbs		2
word		29
words		4

3. WATERLOO.

Individuality Frequency, 65.

Failure Frequency, 0.

Allies fighting		1
Amiens		1
Amsterdam		1
Asia		1
Austerlitz	(1)	2
battle	(22)	233
battle-field		1
battle-ground		1
beer		1
Beethoven		1
Belgian		1
Belgians		1
Belgium	(3)	15
Berlin		1
bird		1
Blenheim		1
Blucher	(2)	10
Bonaparte		3
bridge		1
brother		1
Brussels	(1)	4
Bunker Hill		1
Cedar Falls		1
Cedar Rapids		4
Chelsea		1
Chemnitz		1
church		1
city		1
Courtrai		1
defeat		13
defeats		1
ditch		1
doubtful		1
eighteen-fifteen		1
English		1
fate		1
field		4
fight		3
fighting		2
France		3
French	(1)	4
funny		1
general		1
German	(1)	1
Germans		2
Germany		1
Gettysburg		4
Ghent		1
Hastings	(1)	2
history	(3)	9
home		1
image		1
insurance		1
Iowa	(1)	13
Kaiser		1
Les Miserables		1
lily		1
losses	(1)	1
Louisburg		1
luck		1
map		1
Marne	(1)	1
Metz	(1)	1
military		1
monument		2
Napoleon	(46)	505
Nelson		1
Ney		1
painting		1
Paris	(1)	1
picture		1
plain	(1)	1
Quatre Bras		1
Rheims		1
river		2
Sedan		2
Seneca Falls		1
town		3
Victor Hugo		1
victory		2
war		10
warfare		1
water	(1)	3
Waterbury		2
water lilies		1
water lily	(1)	2
watermelon		1
Watertown		1
weather		1
Wellington	(11)	72
Westminster		1
willow		1
Yorktown		1

4. REFRACTION.

Individuality Frequency, 78.

Failure Frequency, 5.

air		1
amputation		1
angle		5
arithmetic		2
astigmatism		1
atmosphere	(1)	2
back		1
balsam		1
bend		3
bending	(2)	17
bent		2
blackboard		1
blow		1
bound		1
breaking		5
broke		1
broken		1
chemistry		1
clinic		1
college		1
color	(1)	2
colors		1
condensation		1
contraction		3
contrary		1
crystal	(1)	2
crystals		1
curves		1
curving		1
cut		1
deflection		4
D.		1
destruction		1
deviation		1
diagram		2
diffraction	(2)	19
diffusion	(1)	2
dispersion		2
error	(1)	4
eye	(4)	29
eye glass		1
eye glasses		2
eyes	(2)	20
eye sight		3
feldspar		1
fraction		9
fractions		1
glare		1
glass	(10)	76
glasses		10
grating	(1)	2
high	(1)	1
Huyghen		1
ice	(1)	1
incidence	(1)	4
index	(5)	23
indices		1
indirect		1
industry		1
inflection	(1)	4
infraction		5
intensity		1
interaction		1
Latin		1
law		1
leg		1
lens	(3)	36
lenses		2
light	(35)	374
likeness		1
M.		1
mathematics		1
microscope	(2)	5
minerals	(1)	1
mirror		5
muscular		1
Myles Standish		1
myopia	(1)	1
Newton		1
oar		1
obliquely		1
oculist	(1)	3
optical	(1)	2
optician		3
optics		10
period		1
physics	(3)	60
physiology		1
picture		2
polariscope	(1)	1
polarization		3
prism	(1)	24
psychology		1
quartz		1
rafter		1
ray	(1)	4
rays		10
reflect		1
reflection	(11)	68
reflex		2
refractometer		4
refractory		5
refrigerator		2
replacing		1
repulsion	(1)	1
R.		1
science		3
serum		1
slanting		1
Snellen	(1)	1
spectacles		1
spectrum		1
spoon		1
stare		1
strike		1
subtraction		3
sugar		1
sun		6
sunlight		1
think		1
thinking		1
thought		1
transparent	(1)	1
turning		2
ugly		1
undisciplined		1
vision		1
water	(1)	13
waves		1
windows		2
withdrawing		1
word		1
zoology		1

5. ARITHMETIC.

Individuality Frequency, 86.

Failure Frequency, 1.

add		2
adding		1
addition	(3)	34
agony		1
algebra	(11)	91
A.		1
Arabic		1
blackboard		1
book	(2)	45
books	(1)	2
B.		1
brother		1
business		1
calculation	(2)	8
calculations		1
calculus	(2)	5
ciphering	(1)	1
class		2
commercial		2
complete		1
computation	(1)	5
coordinate		1
counting		1
counting frames		1
C.		1
C.		2
decimal		2
decimals		1
declensions		1
difficult		1
difficulty		1
dislike		2
displeasure		1
division		2
dollars		1
easy		1
examination		1
example	(1)	5
examples		3
farm		1
figure		7
figures	(3)	60
five		1
fools		1
formula		1
forty-five	(1)	1
four		4
fraction		6
fractions		20
geography	(6)	44
geometry	(4)	30
German		1
grade		2
grammar	(1)	9
green (book)		1
G.	(1)	1
H.		1
hard		3
hell		1
history		4
interest		3
Kant		1
language		1
lesson		1
logarithms		1
M.		1
mathematics	(5)	80
man	(1)	1
matriculate		1
medicine		1
mensuration		2
mental	(1)	12
metric		1
M.		1
M.		3
minus		1
multiple		1
multiplication	(6)	29
multiply		2
multiplying	(1)	3
music		1
Newton	(1)	1
N.		1
notation		3
number	(12)	85
numbers	(16)	131
numerals		1
one		2
order		1
pedagogue		1
pencil		3
percentage	(1)	4
plus		3
practice		1
problem	(1)	11
problems		10
progression		1
proportion		1
quaternions	(1)	1
rapidity		1
R.	(1)	1
reading		2
R.		1
rudimentary		1
R.		1
scholar		1
school		25
school days		1
science		5
seven		1
simple		1
six	(1)	2
slate	(1)	1
spell		1
spelling	(3)	21
square root		1
standard		1
standard tests		1
student		1
study	(2)	15
subtraction		1
sum	(1)	11
sums	(1)	11
tables		1
teach		1
teacher		5
teaching		3
ten		1
text		1
thirty-four		1
three		1
three r's	(1)	2
torn		1
trigonometry		3
trouble	(1)	2
twice		1
two	(2)	14
two plus two		1
two times two		1
unpleasantness		1
W.		2
W.		1
W.		1
word		1
work		4

6. BOTANY.

Individuality Frequency, 122.

Failure Frequency, 0.

alchemy		1
algae		1
algebra	(1)	4
analysis		1
analyzing		1
anatomy		1
astronomy		1
bacteria		1
bay		2
biogen		1
biology	(2)	25
bird		1
blue		1
blue book		1
book		8
books		1
B.		1
bug		1
bugs	(1)	3
butter		1
buttercup		1
buttermilk		1
buttons		1
cabbage		1
calisthenics		1
calyx	(1)	1
chemistry	(2)	3
chlorophyll		2
class	(1)	1
college		2
C.		2
C.		1
corn		1
corolla		1
corona		1
C.		1
course		1
crucial		1
cryptogam		1
cryptogamic	(1)	2
C.		1
daisies		1
daisy		1
dandelion		2
department	(1)	1
diagram		1
difficult		1
dissection		1
drawings		1
dry		1
D.		1
earth		1
examination	(1)	2
experiments		1
fellowship		1
fern		1
ferns		2
field		1
fields		1
floriculture		1
flower	(8)	121
flowers	(8)	205
F.		1
garden		1
geography	(2)	8
geology	(3)	23
geometry		2
George Ade		1
geranium		1
G.		1
girls		1
good		1
grass		1
G.	(1)	6
Greek		1
green		2
H.		1
hate		1
hepatica		1
herbarium		3
herbs	(1)	1
histology		1
history		1
H.		1
honeysuckle		1
horticulture		1
house		1
Hunter		1
H.		1
ignorance		1
interesting		1
J.		1
laboratory	(1)	8
lamp		1
Latin		1
leaf	(1)	8
leaves		11
lecture		1
L.		1
L.		1
lobate		1
magnifier		1
manual		1
materia medica		1
M.		1
methodic		1
microscope		2
microscopy		1
M.		1
mother	(1)	2
nature		2
M.		1
oak	(1)	1
one		1
one B		1
orchid		1
pansies		1
paramoecium		1
petal		3
physics		3
physiology		4
picture		1
P.		1
plant	(16)	85
plant life		1
plants	(20)	144
professor		1
psychology		3
pterodactyl		1
R.		1
R.		1
R.		1
roots		1
rose		7
roses		1
sassafras		1
school		5
S.		1
science	(4)	27
sensibility	(1)	1
sister		1
soil		1
specimens		1
stamen		1
S.		1
structure		1
study	(3)	11
teacher		3
teaching	(1)	2
text book		1
T.		1
tree		2
trees		5
tulip		2
T.	(1)	2
vermicelli		1
violets		1
walks		1
W.		1
willow tree		1
wood		2
woods		1
W.		1
work		1
zoology	(16)	108

7. ISOMERISM.

Individuality Frequency, 168.

Failure Frequency, (3) 214.

acid		1
aldehydes		1
algebra		3
alike	(1)	2
allomorph		1
allotropy		1
angle worm		1
animal		1
atoms	(1)	1
barometer		1
benzene	(1)	2
biology	(1)	1
blankness		1
carbon		5
cataclysm		1
chain		1
change		1
changing		1
chart	(1)	2
chemical	(3)	5
chemicals		1
chemistry	(28)	109
circles		3
climate	(1)	1
cobalt		1
cold		1
college		1
compounds	(1)	2
concentric		1
constitution		2
crystal	(4)	13
crystallization	(3)	1
crystallography		5
crystals	(4)	15
cube	(1)	1
curve	(1)	1
definition		1
degrees		1
derivation		1
diagram		2
dictionary	(1)	11
differential		1
difficult		1
disease		1
dream		1
eantiotropy		1
earth		1
electricity		1
equal	(3)	30
equality	(1)	9
equal parts		1
equals		1
esoteric		2
evenness		1
examination	(1)	1
experiment		1
eye		1
eyes		2
feldspar		1
form		1
formaldehyde	(1)	1
formula		1
geographic		1
geography		12
geology	(1)	2
geometry	(3)	25
glove		1
graduate	(1)	1
Greek		13
group	(1)	1
handsome		1
hard		1
haziness		1
heat	(1)	24
heat lines		1
homogeneity	(1)	1
homogeneous		1
H.		1
hyperbola		1
hypnotism		1
hysteria		1
ice		1
Iceland		1
icicle		1
icicles		1
iconoclast		1
ignorance		3
incomprehensible		1
inequality		1
insomnia		5
investigation		1
ism		1
isobars		1
isochronism		1
isodynamic		1
isolated		1
isomere	(1)	4
isomergraph		1
isomeric		2
isometric	(1)	35
isoperimetric		1
isopometric		1
isos	(1)	4
isosceles	(1)	33
isotherm		15
isothermal		7
isothermic		3
isothermism		1
isotherms		1
isotropic	(2)	3
isotropism	(1)	1
isotropy	(1)	1
ketone		1
lens		1
light	(1)	16
like	(1)	5
likeness	(1)	8
line		2
lines		10
man		1
mannerism		1
map		1
mathematics		9
matter		1
meaning		1
measure		2
measurement	(1)	4
meridians		1
mern		1
mesmerism	(1)	4
metamerism		3
metamorphic		1
metamorphism		1
metaphysics		1
meter		1
mica		1
microscope		1
M.	(1)	1
model		1
models		1
moment		1
movement		1
music		1
mysticism		1
N.		1
nucleus		1
one		1
optic		1
optical		1
organic	(1)	7
organic chemistry		1
O.		1
pane		1
paraffin		1
Pasteur		1
pentane		1
philology		1
physics	(2)	18
physiology		1
poetry		1
polarization		1
polymer	(1)	1
polymeric		1
polymerism	(2)	10
polymorphism		1
precision		1
pressure		1
prism	(1)	5
problem		1
proportion		1
protoplasm		1
psychology		1
quartz		1
question		2
racemic		1
radiator		1
refraction		1
rhetoric		2
rubbish		1
same		4
same form		1
sameness		2
science		5
scientific		1
seismograph		1
separate		1
similarities		1
similarity	(3)	6
sleep		14
sleepiness		2
sleeplessness		4
sleepy		1
socialism		1
somatic		1
something equal		1
somnambulism		9
somnambulist		5
spar		1
speech		1
starch	(1)	1
stereo		2
stereochemistry		3
stoichiometry		1
structure		1
substances	(1)	1
sugar		1
sugars		2
Sumirians		1
summarization		1
summer		2
sun		1
symmetrical		1
symmetry		1
synchronism		1
tangent		1
tartaric	(2)	4
tautology		1
tautomerism		1
technical	(1)	2
temperature		6
term		1
tetrahedral		1
tetrahedron		1
theory		1
three		1
tissues		1
triangle	(1)	14
triangles	(1)	1
trigonometry		5
two		1
understand		1
uniform		1
uniformity		1
warmth		1
waves		1
weather		3
weather chart		1
word		3
zoology		1

8. PORTUGAL.

Individuality Frequency, 95.

Failure Frequency, 1.

adjacent		1
Africa		1
Alfonso		5
alliance		1
ally		1
armadillo		1
army		1
Atlantic		1
Belgium		1
Bermuda		1
black		1
Braganza	(1)	1
Brazil		2
brown		1
Cabral	(1)	1
Camoens		1
Canary Islands		1
cap		1
cape		1
capital		2
C.		1
child		1
city		3
coast		2
Coimbra		2
Columbus		2
Comosh		1
continent		1
country	(6)	84
dago		1
darkness		1
Delagon Bay	(1)	1
distance		1
earthquake	(1)	1
Emanuel		5
England		3
English		1
Europe	(1)	27
European		1
explorer		1
Farragut		1
fishing		1
foreigners		1
France	(1)	6
G.		3
geese		1
geography	(1)	1
Gibraltar		1
government		1
grapes		1
Greece		3
Greenland		1
Guiana		1
guinea		1
Hayti		1
heat		1
Iberian		1
India		1
insurrection		1
island		1
Italy		3
king	(2)	29
King Alfonso		1
King Manuel	(1)	1
kings		1
knavery		1
land		6
language		1
Lisbon	(12)	74
location		3
Lopez		1
Madrid	(1)	3
Maine		1
man		2
Manuel	(2)	29
map	(3)	31
maps		1
Martha's Vineyard		1
Mediterranean		1
mill race		1
mountains	(1)	1
nation	(1)	3
navigator	(1)	1
niggers		1
ocean		1
Oporto		3
peninsula		4
people		1
person		1
Peru		1
pirates		1
politics		1
porch		1
port		3
portage	(1)	1
Port Juan		1
Porto		1
Portuguese	(2)	11
president		1
prince		1
principality		1
prism		1
queen		1
Quito	(1)	1
republic	(1)	13
revolution		9
river		1
rocky		1
romantic		1
Rome		1
Roumania		1
sea		1
shape	(1)	1
ship		1
small		3
South America		3
Spain	(49)	478
Spaniard	(1)	1
Spanish	(2)	9
state	(2)	11
S.		1
strip		1
T.		1
troops		1
troubled		1
Turkey		1
Uruguay		1
Venice		1
war	(1)	10
water		1
wine	(1)	3
W.	(1)	1
yellow		2

9. AMOEBA.

Individuality Frequency, 150.

Failure Frequency, (1) 36.

albumen		1
ameliorate		1
amethyst		1
amoeboid		2
anaemic		2
anatomy		1
animal	(12)	108
animalcule	(2)	7
animal life		1
animals		1
ant		2
atom		3
bacilli		1
bacillus	(1)	1
bacteria	(2)	6
bacteriology		3
bacterium		1
B.		1
beginning		3
biology	(4)	83
birth		1
blood		1
body		2
botany		12
bug	(2)	15
bugs		8
B.		1
butterfly		1
C.	(1)	1
cell	(3)	51
cells	(1)	3
cellular		1
chart		1
chromatin		1
cilia		4
C.		1
C.		1
cocoon		1
C.		1
contractility		1
corpuscle		1
corpuscles		1
C.		1
crawl		1
crawling		1
cryptogamic	(1)	1
cytoplasm		1
Darwin		1
D.		1
diagram		1
dictionary		1
differential		1
difficult		1
difflugia		1
diphtheria		1
D.		1
dysentery		10
ecology		1
education		1
egg		3
E.		1
engulfment		1
evolution		5
fauna		1
field		1
first		1
fish		6
flat		1
float		1
flow		1
flower		1
flowers		1
foot		1
form		4
fossil		1
fresh		1
friend	(1)	1
frog		2
gelatinous		2
Geneva		1
geology		1
geometry		1
germ	(1)	9
G.		1
globule		1
green		1
Haeckel		1
haematococcus		1
H.		1
heart		1
histology		1
histolytic		1
histolytica		1
hydra		4
inert		1
infinitesimal		1
infusoria		1
infusorian		1
insect		1
irregular		1
jar		1
jelly	(4)	20
jelly-fish	(1)	9
jelly-like		2
J.	(1)	1
knife		1
laboratory		3
lamp		1
lecture		1
life		16
light	(1)	1
limax	(1)	1
little		3
living cell		1
L.		1
lowest	(1)	2
L.		1
man		2
me		1
microbe	(1)	2
microorganism		2
microscope	(3)	37
microscopic		1
minute		1
molecule		2
monocellular		1
motility		1
motion		1
movement	(1)	3
mud		1
mussel		1
natural history		1
neuron		1
nitella		1
nucleus		6
omega		1
one cell		1
organism	(1)	7
paramnesia		1
paramoecium	(7)	32
parasite		4
pastoral		1
patch		1
penicillium	(1)	1
physiology		4
picture	(1)	4
plant	(1)	7
plasmodium		1
polyp		1
primitive	(1)	3
primordial	(1)	1
proteus	(4)	14
protista		1
protoplasm	(7)	54
protozoa	(11)	67
protozoon	(4)	25
protozoons		1
pseudopod		2
pseudopodia	(1)	5
pseudopodium		1
pseudopods		1
psychology		5
reactions		1
read		1
rhizopod	(1)	1
rhombus		1
round		1
S.		1
science		3
sea		1
secondary education		1
shape		1
shapeless		1
shapes		1
silkworm		1
simple		4
slide	(1)	2
slime		1
slimy		1
small	(1)	15
small animal		1
smallest		1
smallness		1
S.		1
soft		2
somewhere		1
sound		1
South America		1
spot		1
squirming		2
star		1
statue		1
S.		2
syphilis		1
technical		1
teeth	(1)	1
tentacles		1
tiny		1
tomorrow		1
T.		1
unicellular	(2)	5
unseeable		1
vacuole		2
voting		1
vulgaris		1
water	(2)	14
water lily	(1)	1
weakness		1
wiggle		1
wiggling		1
W.	(1)	1
woolly		1
word		1
worm		2
zoogloea		1
zoology	(4)	60

10. DECLENSION.

Individuality Frequency, 61.

Failure Frequency (1) 3.

ablative		1
addition		2
adjective	(1)	1
adverb		2
afraid		1
ambiguous		1
amo		1
analysis		1
analyze		1
Anglo-Saxon		1
arrangement		2
ascension		2
blackboard		1
bugbear		1
Caesar		1
case		3
cases		1
changing		1
conjugation	(8)	82
conjugations		1
D.		1
decipher		1
declination	(1)	3
decline		9
declined		1
declining	(1)	2
definition		2
der		2
descent		1
description		1
detention		1
diagnosis		1
diagram		1
difficulties	(1)	1
difficulty		1
ending	(1)	1
endings		1
English		5
falling		1
first		3
F.		1
form		4
four		1
French		3
gender		1
German	(1)	12
grammar	(19)	167
grammatical	(1)	1
Greek		3
hic		1
I		1
inflection	(1)	5
interrogation		1
language		7
languages		1
Latin	(8)	91
line		1
list		1
luo		1
masculine		1
mensa	(1)	5
musa		1
noun	(29)	331
nouns	(4)	40
o		1
paradigm		3
paradigms		1
paraphrase		1
parsing	(1)	4
participle	(1)	4
preposition		1
pronoun	(1)	8
school		2
sentence		2
slope		1
speech		1
spelling		1
stars		1
sum		1
sun		1
syntax		1
tabulation	(1)	1
textbook		1
think		1
third		1
trouble		1
tuba		1
turn		1
variation		1
verb	(16)	90
verbs	(1)	6
vocative		1
walk		1
word		12
words	(1)	5
work		2
writing		1

11. BURETTE.

Individuality Frequency, 121.

Failure Frequency (2) 154.

acid	(1)	4
acidity		1
adornment		1
advertisements		1
aigrette		3
alkali		1
analysis	(1)	5
apparatus	(1)	4
apparel		1
autocracy		1
autocrat		1
bacteriology		1
B.		1
barcarolle		1
barette		43
barometer		1
bayonet		1
beaker		2
B.		1
beauty		1
Beirut		1
bereft		1
B.		1
B.		1
biretta		1
Biuret		5
blue		1
bottle		3
bouquet		1
B.		1
brunette		3
brush		1
bureau	(3)	80
bureaucracy		3
bureaucrat	(1)	2
bureaucratic		1
B.		1
burine		1
burr	(1)	2
burro		1
cabaret		1
cabinet		1
cadet		1
call		1
cap		1
carburet		1
catheter	(1)	1
chemical	(1)	6
chemist		1
chemistry	(27)	170
chiffonier		1
china		1
clamp		2
clamp holder	(1)	1
color		2
comb		2
copper		1
cow		1
crystals		1
cubic centimeter	(3)	4
curate		1
curette	(1)	4
dictionary	(1)	2
dish		1
distillation		1
donkey		1
dress		1
dresser		1
drop		1
dopper		4
drops		1
etymology		1
exactness		1
Fehling's		1
figure		1
five c.c.		1
flower		1
fluid	(2)	2
French		18
furniture		9
gas		1
Gay-Lussac		1
geography		1
glass	(8)	51
glass tube		1
glassware	(1)	2
graduate		2
graduation		1
graduations		2
hair		23
hard		1
head		1
hole	(1)	1
hydrochloric acid		2
ignorance		2
India		1
indistinct		1
information		1
instrument		6
ivory		1
jewelry		2
kitchenette		1
laboratory	(4)	37
Laurette		1
liquid	(2)	6
liquids	(2)	2
little		1
machinery		1
man		1
matter		1
measure	(2)	6
measurement	(1)	6
measuring	(1)	5
medicine		2
Millon		1
name		1
number		1
office		2
one		1
organic		1
P.		1
phenolphthalein		3
photography		1
physics		9
pin		3
pipe	(1)	6
pipette	(11)	57
piping		1
qualitative		1
quantitative	(1)	1
reaction		1
reagent	(1)	1
retort		1
Russia		1
Salt	(1)	1
S.		1
science		4
siphon	(1)	2
size		1
S.		1
solution	(2)	6
stand	(1)	3
standardization		1
sterile		1
stop-cock	(1)	1
styles		1
suffragette		1
sugar	(1)	1
Surette		1
surgeon		2
surgery		3
table		1
tablet		1
T.		1
test		8
testing		1
test tube	(1)	7
thermometer		1
thistle tube		1
titrate	(1)	8
titrating		1
titration	(2)	26
tool		1
town		1
tube	(5)	26
unfortunate		1
urine		1
Utrecht		1
valve		1
verb		1
volume		1
volumetric	(1)	2
W.		1
wall		1
war		1
water		7
wearing		1
what		1
woman		1
word		2
yellow		1

12. PHYSICS.

Individuality Frequency, 147.

Failure Frequency, 2.

abomination		1
activity	(1)	1
algebra		1
Alwood's machine		1
A.		1
ammeter		1
anatomy		2
anamoly		1
apparatus	(3)	13
Archimedes		2
astronomy	(4)	16
A.		1
balance		1
balancing		1
ball		1
battery	(1)	1
beauty		1
B.		1
bodies		1
body		1
book	(4)	24
B.		1
botany		2
bottle		1
Boyle		1
Boyle's Law		1
brother		1
building	(1)	4
Bunsen burner		1
burette		1
C.		3
castor oil		1
change	(1)	1
chemist		1
chemistry	(36)	273
cinch		1
class		4
class room		2
C.		1
cold		1
C.		1
college		7
C.	(1)	2
conditions		1
conservation		1
C.		1
course		1
C.		3
crew		1
crucible		1
darkness		1
demonstration		1
department	(1)	2
difficult		3
dislike		1
dogs		1
drudgery		1
dynamics		1
earth		1
electricity	(3)	31
energy	(1)	4
engineering		1
everlasting		1
examples		1
experiment		8
experiments		9
expositions		1
failure		1
F.		1
figs		1
figures		1
force	(3)	9
forces		1
freshmen	(1)	1
fundamental		1
gas		1
geography		1
geology		1
geometry	(1)	2
gravitation		1
gravity		2
G.		1
gumbo		1
G.		1
H.		1
hard		7
hate		1
heat	(1)	10
hemisphere		1
H.		1
high school		4
H.		2
history		1
H.	(1)	1
H.		1
H.		1
H.		1
index		1
instrument		1
instruments		3
interesting		1
iron		1
J.		1
K.		1
kinetic		1
knowledge		2
K.		2
K.		1
laboratory	(3)	64
L.		1
Latin	(1)	1
law		8
laws	(2)	9
lecture	(1)	2
L.		1
L.		1
lever	(1)	5
levers		1
light	(6)	33
line		2
low		1
machine		1
machines		1
magnetism	(1)	2
M.		1
mass	(1)	2
material	(2)	4
mathematical	(1)	1
mathematics	(1)	16
matter	(5)	13
measure		1
measurement		2
measurements		2
measuring		1
mechanical		2
mechanics	(1)	7
medicine		3
metals		1
mine		1
mirror		1
motion		1
motor		1
movement		1
myself		1
natural		1
nature		2
Newton		6
optics		3
P.		1
pendulum		1
P.		1
P.		1
phenomena		3
philosophy		2
physic	(2)	4
physical		2
physician		1
physicist		1
physics		1
physiography		3
physiology		7
P.		1
pressure		1
P.		1
problems		2
profession	(1)	2
professor		3
psychology		1
pulley		1
pulleys		2
radioactivity		1
radium		2
red		1
R.		1
refraction	(1)	4
refractometer		1
regents		1
room		1
salts		1
scales		2
school		6
science	(4)	97
sciences		1
scientific		1
S.		1
shears		1
sinuous		1
S.		1
solid		1
solids		1
sound		15
specific		1
spelling		1
strength		1
study	(1)	23
subject		5
syphon		1
table		2
teacher		3
teaching	(1)	1
telegraphy		1
Tesla		1
test		2
test tube		2
test tubes		1
text		2
text book		1
theory		1
T.		1
T.		1
training		1
U.		1
vacuum		1
vapor		1
V.		1
water		4
weight		4
weights		3
Wellesley		1
Wesleyan		1
W.		1
W.		1
wood		1
work		2

13. HYPERBOLE.

Individuality Frequeney, 128.

Failure Frequency, (1) 10.

adjective		1
aeroplane		1
algebra		2
amoeba		1
analytics	(1)	5
A.		1
apostrophe		1
arc		1
arch	(1)	1
arithmetic		1
astronomy		7
asymptote	(1)	3
asymptotes		1
Aurora Borealis		1
awful		1
axis		1
ball		1
beauty		1
B.		1
blackboard		2
bombast		2
book		2
bowl		1
bridge		1
calculus		2
C.		1
C.		1
chart		1
Cicero		1
circle		11
class		2
coal		1
comets		1
comparison		1
composition		3
cone		1
conic	(1)	2
C.		1
curve	(10)	80
curved		1
curved line		1
curves	(1)	2
daffodils		1
dash		1
diastole		1
dictionary		1
difference		1
difficult	(1)	1
digression		1
doubt		1
E.		1
ellipse	(2)	8
elliptic		1
English	(1)	17
enthusiasm		1
equation		1
exaggerate		3
exaggerated		1
exaggeration	(19)	211
excess		2
excessive	(1)	1
excitement		1
exclamation	(1)	2
expanded	(1)	1
expression		3
extravagance		6
extravagant	(1)	5
extreme	(1)	3
fables		1
false		1
falsehood		1
falsity		1
figure	(3)	53
	(1)	
figure of speech		1
figures		1
F.		1
form		1
F.		1
fraud		1
Frenchman		1
function		2
geography		1
geometric		1
geometry	(10)	55
girl		1
girlish		1
girls		1
grade		1
grammar	(3)	28
grammatical	(1)	1
graphs		1
heavens	(1)	1
high		2
high school		1
high sounding		1
hyacinth		1
hydrophobia		1
hyperbola	(1)	10
hyperboloid		1
hypertrophy		2
hyphen		2
hypostoma		1
hypothesis	(1)	1
imaginatjon		1
impossible		1
indirect	(1)	1
interjection		3
isosceles		1
joke		3
J.		1
Kaiser		1
K.		1
L.		1
language	(1)	7
laugh		1
liar		1
lie	(1)	19
lies		2
line	(1)	12
literature		4
logic		2
lying		2
L.		1
mathematical	(1)	1
mathematics	(5)	47
metaphor	(2)	19
metonomy		3
misconception		1
mispronounciation		1
mountains		1
nouns		1
onomatopoeia		2
oratory	(1)	2
oval		2
page		1
parabola	(9)	61
parabolic		1
parallax		1
parallel		1
parallelogram	(1)	1
participle		1
part of speech		1
personification		3
petrography		1
phrase		1
picture		1
poetry		3
R.		1
rectangular		1
redundancy		2
refraction		1
requa		1
rhetoric	(3)	51
ring		1
school		1
school girl		2
sentence		1
S.	(1)	1
shape	(1)	2
sideral		1
simile		16
sky		1
slang		1
soaring		1
speak		1
speech	(2)	13
statement		2
story	(2)	3
stretched		1
stretching		2
study		1
superfluity		1
superfluous		1
superlative		1
swelled		1
S.		1
synecdoche		7
synonym		6
syntax		1
T.		1
too		2
triangle	(2)	7
trigonometry		5
trope	(1)	1
truth		1
untruth		1
untruthfulness		1
unusual		1
water		1
W.		1
women		1
wonderful		1
word		5
words		2

14. RETINA.

Individuality Frequency, 60.

Failure Frequency, 2.

addition		1
anatomy		1
bluish	(1)	1
body		1
camera		2
cell	(1)	1
cells		2
Charlemagne		1
choroid		4
cigar		1
cinder		1
circle		1
class		1
coat		1
color		1
colors		1
color theory		1
concave		1
cone		1
cones		3
conjunctiva		1
convex		1
cornea		4
corona		1
dark		1
defective		1
delicate		1
diagram	(1)	2
E.		1
eye	(80)	817
eye ball		4
eye glass		1
eyes		6
eye sight	(1)	1
eye strain		1
fatigue		2
fovea		1
G.		1
glass		1
glasses		3
histology	(1)	1
hygiene		1
image		2
iris	(1)	13
king		1
lens		6
light	(2)	9
lining		1
near-sight		1
nerve		2
nerve cell		1
nerve endings	(1)	1
nerves		1
nervous	(1)	2
Netzhaut		1
neuron	(1)	1
oculist	(1)	1
optic	(1)	9
optical	(1)	1
optic nerve		1
optics	(1)	9
periphery		1
photographic		1
physiology	(1)	6
picture		1
pigment	(1)	1
psychology		4
pupil		4
ray	(1)	1
rays		1
retain		1
reticent		1
reticular		1
reticule		2
retinue		2
rod		1
rods		3
sclerotic		1
shape		1
sight	(1)	8
spectacle		1
synapse		1
text-book		1
type		1
unpleasant		1
vision	(1)	6
visual		2
wonder		1

15. COAGULATION.

Individuality Frequency, 104.

Failure Frequency, 4.

accident		2
accumulation		1
agglutination		1
albumen	(6)	33
alcohol		2
alum	(1)	4
aluminium		1
aluminium hydroxide		1
amoeba		1
analysis		1
biology		1
blood	(48)	489
blood clot		1
boy		1
bunching		2
butter		1
buttermilk		1
calcification		1
casein	(1)	1
chemistry	(1)	13
closing		1
clot	(2)	14
clotting		15
clumping		1
coadjustment		1
coagitate		1
coalition		1
coeducation		1
cold		1
collect		1
collection		1
colloid		7
colloidal		1
colloids	(1)	2
complex		1
condensation	(1)	2
condensing		1
conductor		1
congeal	(2)	4
congealing		1
congestion		2
conglomeration		3
congregation		1
conjugation		1
constellation		1
cooperation		3
cream		1
crystallization		1
curd		1
curdle		1
curdling		3
curds		1
cut		1
death		1
deliquescence		1
dictionary		1
diffusion		1
dissolving		1
egg	(11)	68
eggs	(1)	9
egg-white		1
emulsion		1
experiment		1
fibrin		3
filtrate		1
filtration		1
fixation		1
fluid		3
freezing		5
gathering		2
gel		1
gelatin		3
gelatinous		1
geology		1
glue		3
glutenization		1
gluttonous		1
gumminess		1
haemoglobin		1
haemophilia		1
hard		3
harden		1
hardening		7
heat	(1)	4
ice		4
jar	(1)	1
jelly	(3)	14
karyokinesis		1
latex		1
lymph		1
man		1
mass		2
massing		1
medicine		1
melting		1
merging		1
mess		1
milk	(6)	43
milky		1
moisture		1
molasses		2
molecules		1
movement		1
murder		1
necrosis		1
omelet	(1)	1
oscillation		1
osmose		1
particles		1
pathology		1
physics		2
physiology		3
plasma		1
precipitate	(2)	9
precipitation	(3)	11
products		1
proteid	(1)	7
protein	(2)	14
proteins		2
protoplasm		1
psychology		1
regillation		1
rigor caloris		1
safety		1
science		1
sedimentation		1
serum		2
settling		1
silica		1
S.		1
solid		4
solidification		4
solidified		1
solidifying		2
solidity		1
solids		1
solution		2
souring		1
sour milk		1
stick		2
stickiness		1
sticking		3
sticky	(1)	3
stiffened		1
stiffening		2
stuff		1
teacher		1
test		1
thick		5
thicken		2
thickening	(3)	23
thickness		1
thrombin		1
time		3
together		3
union	(1)	2
verb		1
water		2
white		1
white mass		1
whitish		1
wound		2
wounds		2

16. CERVANTES.

Individuality Frequency, 99.

Failure Frequency, (1) 65.

Africa		1
A.		1
art		1
author		17
B.		1
battle		2
biology		1
bone		1
book	(5)	19
books		1
brain		1
Calderon		1
castle		1
cavalier		1
certain		1
cervical	(1)	1
cervix		1
character		1
chivalry		1
Cid		4
city		3
classical		1
comedy		1
Cortez		1
cuneiform		1
Dante	(1)	3
discoverer		1
Disraeli		1
Don Quar Don		1
Don Quixote	(42)	310
drama		2
Dumas		1
Dutch		1
east		1
eccentricity		1
education		2
English		3
exaggeration		1
exploration	(1)	1
explorer		2
famous		1
fiction		2
following		1
France		1
French		8
Frenchman		1
G.		1
general		3
great		1
Greece		1
Greek		2
heroes		1
Hindu		1
historical		2
history	(1)	39
Huerta		1
humor		2
idealism		1
Italian		9
king		1
Latin		4
literary		1
literature	(2)	11
Lope da Vega		1
Machiavelli		1
man		23
mediaeval		1
Mexico		3
Michael		1
Miguel		1
military		1
Milton		1
mind		1
M.		1
monastery		1
mystery		1
mythology	(1)	2
name	(1)	11
Napoleon		1
neck		2
noted		1
novel	(1)	8
novelist		1
oration		1
pageant		1
painter		1
painting		1
Panza		1
person		2
persons		1
Philippines		1
philosopher		6
philosophy		4
photograph		1
picture		1
place		1
plant		1
plants		1
poet	(1)	7
poetry		1
pottery		1
print		1
prison		1
Quixote	(1)	5
Quo Vadis		1
reading		1
romance		1
romantic		1
Roosevelt		1
Rozinante		1
Sancho Panza	(1)	3
satirist		1
Savannah	(1)	3
savant		1
Savonarolla	(1)	1
scholar		1
science		2
scientist		2
scientists		1
seer		1
S.		1
servant		2
servants		1
ship		1
Socrates		1
soldier		1
Spain	(25)	162
Spaniard	(1)	14
Spanish	(7)	85
Spanish literature		1
speech		1
spine		1
story		4
survey		5
surveying		2
surveyor		2
town		1
transit		1
Victor Hugo		1
warrior		1
water		1
wind mill	(2)	4
wind mills	(2)	7
wise		2
word		4
writer	(1)	12
writing		1

17. FRANCHISE.

Individuality Frequency, 102.

Failure Frequency, 1.

act	(1)	1
agreement		1
American		2
anti-suffrage		1
attraction		1
automobile		1
ballots		1
ballot	(1)	5
baseball		1
bicycle		1
bill		1
Boulder		2
business		4
car		4
car fare		1
cars		2
charter		8
Chicago		1
choice		1
cities		1
citizen		2
citizenship		3
city	(6)	77
city government		1
civics		3
civil		1
code		1
commerce		1
commission		1
company		3
compromise		1
consent		1
constitution		1
contract		5
corporation	(3)	16
corporations		1
country		3
court		1
crook		1
daughter		1
debt		1
democracy		1
department		1
dictation		1
disenfranchise		1
disfranchise		1
document		2
D. U. R.		1
economics		2
election		6
electoral	(1)	1
electric		1
embargo		1
endorsement		1
enfranchise		1
England		1
entanglement	(1)	1
equal		6
equality		1
Europe		1
favor		2
firm		1
forfeit		1
Francais		1
France		3
Francis Joseph		1
frantic	(1)	1
fraud		2
free		4
freedom	(1)	17
French		2
friendship	(1)	1
government	(2)	26
graft	(2)	9
grant	(1)	4
granting		2
history		7
honor		1
house		1
independence		1
interborough		2
Italian		3
Kansas City		1
land		1
law	(2)	29
lawyer		1
league	(1)	3
lease		1
legal		5
legality		1
liberation		1
liberty		4
license		1
light		1
liquor		1
loss		1
M.		1
make		1
man		1
merchandise		1
money		4
municipal	(5)	17
municipality		5
M.		1
negro	(1)	11
negroes	(1)	1
New York		1
niggers		1
Pankhurst		2
paper		1
papers		1
people		1
permission		3
permit		4
petition		1
policy		1
politician	(1)	2
politics	(3)	17
Portland		1
privilege	(1)	10
public		5
railroad	(4)	46
railroads	(1)	9
railway	(3)	36
railways		2
regret		1
regulations		1
right	(1)	8
rights		3
road		1
school		1
selfish		1
slave		1
slavery		2
slaves		3
state		3
statement		2
steal		1
street	(1)	1
street car		20
street cars		3
street railways		1
strike		1
subway		1
suffrage	(5)	79
suffragette	(1)	6
suffragettes	(1)	2
suffragism	(1)	2
suffragist		1
tariff		1
tax	(2)	8
taxes		1
town	(2)	5
traction		1
trade		1
tramway		1
transportation		1
treaty		1
trolley	(1)	5
universal		1
unlimited	(1)	1
utilities		1
utility		1
Venezuela		1
ville franche		1
vote	(23)	151
voter	(1)	3
votes	(2)	23
voting	(4)	20
war		1
water		1
woman	(1)	31
woman's suffrage	(2)	3
women	(7)	64

18. SUBSTRACTION.

Individuality Frequency, 55.

Failure Frequency, 0.

abacus		1
accounts		1
add		6
addition	(41)	395
additions		1
algebra		1
Alice in Wonderland		1
analysis		1
arithmetic	(19)	253
attraction		1
Austrian		2
away		2
baby		1
blackboard		1
book		1
Burroughs		1
calculation		4
children		1
contraction		1
C.	(1)	1
credits		1
dash	(1)	2
deduct		1
deduction	(1)	3
detraction		1
D.		1
difference	(2)	8
differences		1
diminution		1
distraction		2
division	(3)	10
dollars		1
elimination		1
example		2
father		1
figures	(3)	21
four		1
fraction		2
fractions		1
fundamentals		1
glass		1
grade		1
inverse operation	(1)	1
kindergarten		1
Latin		1
less	(1)	6
line		2
logarithm		1
loss	(1)	4
machine		1
mathematical	(1)	1
mathematics	(2)	24
method		1
minuend	(2)	6
minus	(2)	29
minus sign	(1)	5
money	(1)	3
motion		1
multiplication		60
multiply		1
number	(1)	7
numbers	(4)	38
numerator		1
operation		3
paper		2
plus		1
poverty		1
problem	(1)	4
problems		1
process	(1)	5
reduce		1
remainder		1
removal	(1)	1
school		4
separation		3
sign		2
stocks		1
subdivision		1
subnormal		1
subtrahend	(1)	2
sum	(1)	11
table		1
take		4
taking away	(1)	4
teaching		1
tests		1
twenty-five		1
two		3
under	(1)	1
withdrawal		1
word		1
work		2
wrong		1

19. METABOLISM.

Individuality Frequency, 169.

Failure Frequency, (2) 57.

absorption		2
activity		2
after		1
albumen		1
algebra		1
alteration		1
amoeba		2
anabolic		1
anabolism	(6)	39
anaemia		1
anatomy		1
animal	(1)	6
animals		3
ascending		1
assemblage		1
assimilate		1
assimilation		10
atavism		1
Atwater		1
B.		1
bimetallism		1
bio-chemistry		1
biology	(7)	40
blood		19
blue-yellow		1
body	(3)	19
book		1
botany	(1)	9
boy	(1)	1
brain		1
build		2
building		8
building up		3
burning	(1)	2
cages		1
cannibal		1
carbohydrates		1
carbonic acid	(1)	1
catalysis	(1)	1
Catholicism		1
cell	(2)	13
cell division		1
cells	(2)	3
change	(12)	110
changeableness		1
changes		2
changing	(1)	3
chemical		1
chemistry	(8)	44
chewing		1
C.		1
coagulation		2
color-blind		1
combination		1
concentration		1
construction		1
constructive		1
converting		1
curve		1
cycle		1
cylinder		1
death		4
decomposition	(1)	1
destruction		3
destruction of tissue		1
development	(1)	1
diabetes		1
diathermancy		1
diet		1
dietetics		2
difficult		1
digestion	(8)	41
digestive		1
dinner		1
disease		1
divisions		1
doctor		1
eat		1
eating		2
eccentric		1
education		1
electricity		1
elision		1
embolism		1
energy		1
enigma		1
esoteric		1
excretion		1
experiment		1
eye		1
fermentation		1
F.		1
food	(9)	47
form		1
function		3
galvanize		1
gather		1
G.		1
G.		1
gout		1
grammar	(1)	3
Greek		6
growth	(2)	19
Hamurabi		1
hard		1
health		2
heat		1
Heavens		1
H.		1
highbrow		1
hygiene		1
hyperbola		1
hyperbole		2
indigestion		1
infants		1
inhibition	(1)	1
iron		1
karyokinesis		2
katabolic		1
katabolism	(2)	77
kinetic		1
life	(2)	11
light		1
man	(1)	2
meals		1
medical		1
medicine		12
M.		1
metabolic		1
metal	(1)	17
metallic		1
metallurgy		4
metals		1
metamorphosis		1
metaphor		1
metaphysics		1
metastoma		1
metathesis		1
meteorology		1
method		1
M.		1
microscope		1
mind		1
mines		1
mirror		1
mixture		1
monograph		1
more		1
motion		1
mouse		1
movement		1
moving		1
multiplication		1
mutabile		1
nearness		1
nerves		1
nitrogen		1
nourishing		1
nourishment		4
nutriment		2
nutrition	(1)	15
nutritious		1
operation		1
organic		1
organism		4
osmosis		3
oxidation		1
Ph. D.		1
philosophy		2
phosphorous		1
photosynthesis		1
physical		2
physician		1
physics		6
physiological		1
physiology	(9)	70
plant		4
plants		1
poison		1
problem	(1)	1
process	(1)	6
processes		1
progress		2
proteid		2
protein	(1)	6
protoplasm	(2)	3
psychology		11
purin		1
puzzle		1
rabbit		1
rhetoric		1
R.		1
R.		1
R.		1
school		1
science		11
scientific		1
sesquipedalian		1
sickness		1
skin		1
sociology		2
species		1
Stoffwechesel	(1)	1
stomach		1
stone		1
storage		1
study		2
synthesis		1
synthetic		1
system		1
table		1
tables		1
tabulation		1
tearing		1
telephone		1
thought		1
tissue	(1)	3
transfer		1
transference		1
transformation		1
transposition		1
tuberculosis		1
union		1
unknown		1
upset		1
urea	(1)	1
vital		1
V.		1
waste	(2)	2
words		1
workings		1
zoology	(2)	10

20. PREDICATE.

Individuality Frequency, 58.

Failure Frequency, 1.

abdicate		1
action		4
adjective	(2)	28
adverb		8
affirm		2
analysis		2
are		1
arithmetic		1
assert	(1)	2
assertion		1
assertive		1
association		1
assumption		1
attribute	(1)	3
be		1
before		1
book		1
characteristic	(1)	1
clause		1
conclusion		1
conjugation		1
coplative		1
copula		1
declare		1
declension		1
description		1
diagram		5
dignity		1
end		3
English		5
French		1
German		2
grammar	(15)	121
half		1
hopeful		1
hypothecate		1
ill		1
impersonal		1
is		3
language		9
Latin		2
lie		1
logic		6
man		1
Massachusetts		1
meaning	(1)	1
modifier		1
motion	(1)	1
multiplication		1
nomination		1
nominative	(1)	4
noun	(6)	85
numerator		1
object	(2)	18
objective		2
orthodox		1
parsing		1
part		1
participle		3
part of speech		2
past		1
pedagogue		1
petticoat		1
philosophy		1
postulate	(1)	1
predatory		1
predicament		1
predict	(1)	3
preface		1
pronoun	(1)	3
prove	(1)	1
rhetoric		2
running		1
R.	(1)	1
say		1
see	(1)	1
sentence	(5)	67
Spanish		1
speech		3
statement		3
subject	(28)	271
subjunctive	(1)	2
substance		1
substantive		2
suggestion	(1)	1
suppose		1
syndicate		2
syntax	(1)	2
think		2
thinking		1
verb	(25)	253
verbs		4
was	(1)	2
word		2
writing	(1)	1

21. MOLLUSC.

Individuality Frequency, 96.

Failure Frequency, 11.

age		1
amoeba	(2)	8
amphibious		1
anatomy	(1)	1
anemone		1
animal	(8)	111
animals		5
antedeluvian		1
architecture		1
arthropod		3
atom		2
biology	(2)	23
bird	(1)	1
bivalve	(1)	14
bone		2
botany		3
brachipod		2
bug		1
building		2
California		1
Catholic		1
cell		2
cephalopod	(2)	2
chemistry		1
clam	(16)	125
clams	(1)	4
class		1
classification		1
coagulation		1
coast		1
coil		1
comparative anatomy		1
coral		1
crab	(1)	10
crawfish		1
creature		1
crustacea		3
crustacean	(3)	15
crusty		1
ctenophore	(1)	1
cystoid		1
D.		1
Devonian		1
drama		1
earthworm		1
echinoderm	(1)	4
Egypt		2
Egyptian		2
elephant		5
elephants		1
evolution		1
exostceleton		1
feed		1
fish	(3)	62
fly		1
form		1
fossae		1
fossils		1
gastropod		1
geology	(1)	15
giant		1
group	(1)	1
hard		1
hard shell		1
heathen		1
history		1
hydrozoa		1
invertebrate	(2)	5
invertebrates		1
islands		1
ivory		1
jelly fish		1
laboratory		1
Latin		1
lazy		1
life		2
lobster		3
low		1
lower forms		1
mammal		1
mastodon		2
microorganism		1
molasses		1
mole		1
molecule		3
molest		1
M.		1
mollusca		1
molluscan		1
molluscoidea	(1)	1
moose		1
mouse		1
museum		2
mussel	(2)	12
mytilus edulis		1
natural history		2
north		1
obelisk		1
ocean		4
octopus		1
odontophore		1
O.		1
ox		1
oyster	(13)	117
oysters	(1)	5
paleontology		1
phylum		2
planorbis		1
play		8
polyp		1
pulp		1
reef		1
repulsive		1
river		1
Russia		1
science		3
sea	(2)	16
sea coast		1
sea shell		1
sea shore		2
shell	(11)	136
shell-fish	(8)	37
shells	(1)	13
shore		1
size		1
skeleton		1
small		1
smell		1
snail	(6)	16
soft	(1)	7
sponge		2
star-fish		1
story		1
S.		1
sucker		1
teeth		1
Tennyson		1
teredo		1
tusk		2
type		1
Venus		1
Venus mercenaria		1
vertebrae		1
vertebrate		2
water		5
whale		2
worm	(1)	3
zoology	(6)	154

22. INQUISITION.

Individuality Frequency, 105.

Failure Frequency, 5.

acquire		1
acquiring		1
acquisition		2
Alva		1
anarchism		1
ask		3
battle		2
bigotry	(1)	3
burning		1
Calvin		1
Catholic	(3)	32
Catholic Church	(4)	4
Catholicism		4
Catholics		3
cell		1
century	(1)	1
Cervantes		1
Christian		1
church	(1)	11
Coligni		1
committee		1
court		5
cruel		1
cruelty		5
curiosity		2
dark ages	(1)	1
death		1
demand		1
devilment		1
disposition		1
doctor		1
Dominicans	(1)	1
early		1
education		1
English		1
equisition		1
Europe		1
events		1
examination		1
exposition		1
exquisition		1
faith		1
force		1
France		15
French	(1)	3
French Revolution		2
funeral		1
Galileo	(1)	1
girl		1
government		1
governments		1
grass	(1)	1
guillotine		4
hanging		1
H.		1
heresy		1
heretic	(1)	1
history	(5)	34
Holland		1
holy		1
horrible		2
horror		4
horrors		1
Hugenots		1
ideal		1
imposition		1
Indian		1
indifference		1
indulgence		1
inquire		1
inquiry	(1)	8
inquisitive		4
inquisitiveness		1
interrogation		1
intolerance		1
introspection		1
invasion		1
investigation		3
Isabella		1
Japan		1
Jesuit	(3)	6
Jesuits		4
Jews	(1)	4
judgment		1
jury		2
kill		2
law		3
lawyer		1
L.		2
Louis XIV.		1
low		1
Loyola	(1)	3
masonry		1
martyrs		1
M.		1
mediaeval		2
mediaevalism		2
Mexico		2
middle ages		3
mind		1
monk		3
monks		1
murder		4
oppression	(1)	1
pain		4
papacy		1
paper		1
people		1
persecution	(1)	13
Philip	(1)	3
picture		1
pictures		1
Poe		1
Pope		2
priest		4
priests		1
Protestantism		1
punishment		3
question	(1)	11
questioning	(1)	7
questions	(1)	3
rack		1
rain		1
Reformation		4
religion	(1)	11
Renaissance		1
require		1
requisition		6
research		1
revolution		2
Roman	(1)	1
Romanism		1
Romanists		1
Romans		1
Rome		3
scaffold		1
search		1
searching		1
sentence		1
sixteen-twenty	(1)	1
Spain	(32)	316
Spaniard		7
Spaniards	(1)	2
Spanish	(21)	222
Spanish art		1
spikes	(1)	1
spurious	(1)	1
stake		1
strife		1
suffering		3
suggestion		1
territory		1
terror		1
test		1
thumbscrew		2
Torqurmada	(1)	7
torture	(7)	45
trial		5
tyranny		1
unfair		1
uprising		2
vengeance		1
Venice		1
war		2
Washington Irving		1
Westward Ho		2
witches		1
wrong		2

23. AMPHIBIOUS.

Individuality Frequency, 109.

Failure Frequency, 7.

alligator	(2)	14
ambidextrous		10
ambiguous		2
amorphous		2
ampher		1
amphibia	(2)	2
amphipod		1
amphitheater		2
amplitude		1
ancient		1
animal	(3)	87
animals	(1)	10
anthropology		1
aquatic	(1)	1
axolotl		1
bath	(1)	1
batrachia		1
batrachian	(2)	4
bear		1
beast		1
beaver		3
biology	(2)	17
bird	(1)	3
birds		1
bite		1
blank		1
blue fish		1
body		1
both		6
carnivorous		1
centipede		1
cetacean		1
chair		1
Christian		1
crawling		1
creature		1
crocodile	(2)	10
Darwin		1
definition		1
dextrous		2
dimorphic		1
dioecious		1
dog		1
dossil		1
double		9
double life		1
doubtful		4
duck	(2)	6
duckbill		1
earth		1
eat		1
eating		1
elephant		1
encyclopaedia		1
English		1
faults		1
feet		2
fibre		1
fish	(5)	67
fishes		2
fishy		2
flappers		1
fodder		1
foot		1
frog	(28)	189
frogs	(4)	18
gastronemia		1
geological		1
geology		8
grass		1
Greek		1
hands		3
herb		1
herbivorous		1
hippopotamus	(1)	9
historical		1
horse		1
ibid		1
Ibsen		1
Irishman		1
invertebrate		1
K.		1
K.		1
land	(1)	11
land and water	(1)	4
leaf		1
left		1
legs		2
lie		1
life		2
liniment		1
lizard	(1)	3
lobster		1
mad		1
mammal		2
mammals		1
man		1
many		1
marine	(1)	2
meat		1
mermaid		1
monster		2
mortal		1
mud-puppy		1
myself		1
nautical		1
natural habits	(1)	1
Necturus		1
ocean		3
physiology		2
plants		1
pollywog	(1)	2
psychology		1
quadruped		1
race		1
recapitulation	(1)	1
reptile	(1)	19
reptiles	1)	5
reptilia	(1)	1
rhinoceros	(1)	2
rocks		1
salamander	(2)	12
S.		1
scaled		1
science		2
sea	(1)	8
seal		7
sea-lion		2
sea-turtles	(1)	1
shapeless		1
ship		1
shore		1
shores		1
sleep		1
slow	(1)	1
small animal		1
snake		1
species		1
story	(1)	1
submarine	(1)	1
swamps		1
swim		1
swimmer	(1)	2
swimming		5
swims		1
tadpole		1
technical		1
teetotaler		1
toad		4
toads	(1)	2
T.		1
T.		1
truthful		1
turtle		7
turtles		1
two		5
understand		1
vertebrate		3
walking		1
walrus		2
water	(17)	206
water-dog	(1)	1
water-loving		1
watery		2
wet		2
whale	(3)	26
whales		1
worm		2
zoology	(2)	31

24. DECIMAL.

Individuality Frequency, 58.

Failure Frequency, 0.

algebra	(1)	2
anecdote		1
arithmetic	(6)	85
army		1
banking		1
bills		1
blackboard		1
capital		1
centimeter		2
circulating		1
classification	(1)	2
coinage		1
comma		2
common		4
compound		1
concentration	(1)	1
contract		1
day		1
Decameron		1
December	(1)	2
decimal point		1
decimate	(1)	3
decipher		1
denomination		1
desecrate		1
division		1
divisions		1
dollar		3
dollars		1
dot		7
duodecimal		2
eight-tenths		1
electric		1
equation		1
equivalent		1
figure		6
figures	(1)	11
five-tenths		1
fortunes		1
fraction	(38)	372
fractional		2
fractions	(2)	37
France		1
French	(1)	3
geometry		1
Hindoo		1
hundred		1
hundredth		2
integral		2
interest		1
logarithm		1
mathematical		1
mathematics	(2)	12
measure		3
meter	(1)	2
metric	(1)	10
money	(1)	4
notation	(1)	5
noun	(1)	1
number	(10)	44
numbers		15
one		1
one-hundredth	(2)	2
one-tenth		2
π.		1
part	(2)	7
parts		2
percent		4
percentage	(1)	6
period	(1)	20
picture	(1)	1
place	(1)	4
point	(13)	135
position		1
punctuation		1
revision		1
school		2
short		1
sentence		1
septem		1
small		1
statistics		1
stick		1
subtract		1
subtraction		4
sum		1
system	(3)	20
teaching		1
tease		1
ten	(2)	47
ten cents		1
tenth	(2)	26
tenths		9
thousandth		1
two		1
unit		1
verb		1
vulgar		1
vulgar fraction		1
whole	(1)	2
zero	(1)	6
zeroes		1

25. HYDRAULIC.

Individuality Frequency, 56.
Failure Frequency, 1.

aqueduct		1
canal	(1)	1
cement		2
chemics		1
chemistry		3
civil		1
compression		1
conservation		1
C.		1
cow		1
crane		3
dam		1
dynamic		1
electric		2
elevator	(1)	5
elevators		1
energy		1
engine	(1)	15
engineer		7
engineering	(3)	30
engines		1
flow		1
force		7
force pump		2
gauge	(1)	1
gold		2
G.		1
grade		1
gravity		1
hammer		1
H.		1
heavy		1
hose		1
hydra		1
hydrangea		1
hydro-		1
hydrolysis		1
hydrostatic	(2)	4
hydrostatics	(1)	1
hydrozoon		1
laboratory	(1)	4
land		1
Leonardo da Vinci		1
lift		1
lifting		1
lime	(1)	1
machine		7
machinery		6
mechanics	(1)	4
M.		1
mine		3
mining		11
P.		1
physics	(4)	45
picture		1
pipe		1
piston		1
plant		1
penumatic	(1)	2
power	(4)	25
press	(13)	118
pressed bricks		2
pressure	(9)	120
pump	(5)	44
pumping		1
pumps		2
ram	(11)	53
reservoir		1
sanitary		1
science		1
static		1
steam		1
strength of water		1
syringe		1
technology		1
T.	(1)	1
turbine		1
washing machine		1
washout		1
water	(38)	411
water-power		3
water-pressure		2
weight		1
well		1
Z.		1

26. OSMOSIS.

Individuality Frequency, 153.
Failure Frequency, 58.

absorption	(1)	5
action		2
air		1
A.		1
alpha privative		1
anatomy		1
anchylosis		1
apparatus		3
ascent		1
assimilation		2
asthma		1
attraction		1
automatic		1
bacteriology		1
B.		1
between		1
biology		14
bladder	(1)	1
blood	(4)	42
blood-vessel		1
blotter		2
blotting		1
bone	(1)	28
bones		13
bony		1
book	(1)	1
botany	(1)	16
breathing	(1)	3
bulrushes		1
cane sugar		1
capillary	(1)	4
catalysis		1
cataphoresis		1
cell	(1)	7
cells		3
chamois skin		1
change		19
changing		1
chemical		1
chemistry	(3)	46
chemosis	(1)	1
circulation		3
clay		1
colloid		1
colloids		1
contraction		1
corpuscle		1
cosmopolitan		1
cosmos		2
cosmosis		2
covering		1
crystallize	(1)	1
crystalloid	(1)	2
death		1
dentistry		1
dialysis		12
dialyzation		1
dialyzer		1
diapedesis		1
diaphragm	(2)	6
dictionary		1
dietetics		1
diffusion	(6)	28
digestion		2
doctor		1
Dutrochet		1
earth		1
effusion		1
egg		28
eggs		3
Egyptian		1
electricity		1
electrolysis		1
endosmosis	(3)	8
exchange		1
exosmosis	(1)	2
experiment		6
eye		1
eyes		1
fake		1
film	(1)	1
filter	(1)	2
filtering		1
filtration		6
flowing		1
fluid		2
fluids		1
food		1
force		2
free		1
fruit		1
fusion	(1)	1
gas	(1)	9
gases	(2)	10
glass		1
hair		1
hardening		3
hormone	(1)	1
H.	(1)	1
hydrolysis		1
hydrostatics		1
hypnosis		1
important		1
integration		1
intestine		1
Iowa		1
jar		1
K.		1
laboratory		1
lameness		1
leaf		1
leak		1
leakage		2
leaves		2
liquid	(1)	6
liquids	(2)	6
lungs	(1)	2
lymph		1
medicine		7
membrane	(20)	109
membranes		2
metabolism		3
molasses		2
molecule	(1)	3
M.		1
Moses		7
most		1
mouth		2
movement		1
moving		1
mystery		1
N.		1
nervous		1
nonsense		1
opal		1
O.		1
Oslerism		1
O.		2
osmometer	(1)	1
osmotic		1
ossification		1
osteopath		1
O.	(1)	2
out through		1
ox		1
oxygen	(1)	3
parchment		3
partition	(1)	1
pass		1
passage		6
passing		3
penetration	(1)	5
percolate		1
percolation		2
permeability		3
permeating		1
permeation		1
Pfeffer	(2)	4
physical		1
physical chemistry	(1)	2
physician		1
physics	(3)	31
physiological		1
physiology		18
plant		12
plants	(4)	11
plasmolysis	(1)	2
porcelain		1
porous		4
porous cup		1
pots		1
pressing	(1)	1
pressure	(9)	63
pressures	(1)	1
principle		1
process		7
professor		1
root	(1)	2
salt		2
sap		1
science		12
scientific		1
sclerosis		1
seep		1
semi-permeable		1
separation		1
sifting		3
skin		11
sleep		2
soak		1
soaking		1
soaking through		1
soil-water		1
solidifying		1
solution	(4)	6
starch		1
stimulation		1
stone		1
straw		1
strong		1
suction		4
sugar	(1)	5
surface tension		1
teacher		1
tension		1
test-tube		1
text-book		1
theosophy		1
thermos		1
thick		1
thistle-tube		1
through		1
tissue		7
tissues		1
transfer		2
transference		2
transformation		1
transfusion		6
transmission		2
transpiration		1
transudation		2
transude		1
tree		1
trees	(1)	1
triangle		1
tube	(1)	3
tuberculosis		1
tubes		1
turgor		1
turn		1
union		1
universe		1
Van't Hoff		1
V.		1
water	(2)	33
wearing away		1
words		1
yeast		1
zoology		2

27. PERCENTAGE.

Individuality Frequency, 102.

Failure Frequency, 1.

accounting		1
addition		5
alcohol		1
algebra		1
apply	(1)	1
arithmetic	(15)	196
average	(1)	5
bank		9
banking	(1)	10
banks	(1)	2
base		3
baseball		2
basis		5
batting		2
bond		1
bonds		2
book		1
business	(1)	9
by the hundred		1
calculation		3
cases		1
cash		1
census		1
character		1
charts		1
class		1
classification		1
column		1
column of figures	(1)	1
commission		1
composition	(3)	10
compound		1
computation		2
constituents		1
contest		1
correct		2
costs		1
death		1
debts		1
decimal	(5)	43
decimal point		1
decimals		6
degree		1
denominator	(1)	1
difficult		2
discount		4
dividend	(1)	1
division		3
dollar	(1)	4
dollars		4
dollars and cents	(1)	1
efficiency		2
error	(1)	5
errors		1
examination		1
example		1
examples		1
expression		1
fail		1
failures		1
fifty	(1)	1
figure	(1)	12
figures	(2)	15
figuring		1
finance		2
five		2
formula		1
four		1
fraction	(8)	72
fractional		1
fractional part		1
fractions		19
gain		2
goal		1
grade		2
grades		3
grocery		1
gymnasium	(1)	1
high		2
hundred	(3)	49
hundreds		1
hundredth		2
hundredths		13
income	(1)	2
increase		1
insurance	(1)	3
interest	(12)	77
interval		2
investment		1
low		1
mark	(1)	7
marks		2
mathematics	(2)	17
mercantile		1
monachal		1
money	(4)	40
multiplication		2
nitrogen		1
no		1
normal	(1)	1
notes		1
nouns		1
number	(3)	20
numbers	(2)	27
nutrition		1
of		1
one hundred	(2)	12
one-tenth		1
overhead		1
part	(3)	23
partial		1
parts		1
per cent	(1)	5
percentage mark		1
percental		1
percentile	(2)	3
per cent sign		10
P.		1
perquisite		1
personage		1
personality		1
picture		1
plant		1
plus		1
point		1
population		1
portion		2
Portugal		1
principal	(1)	5
problems		2
profit		4
proportion		10
purchase		1
quantity		2
rank		1
rate	(2)	11
ratio	(2)	8
reduction		1
regents		1
relation	(1)	1
relative		1
respiration		1
rhythm	(1)	1
rules	(1)	1
salary		2
sale		1
school		4
science		1
seals		1
share		2
sign	(2)	18
six		6
slate		1
small		1
statistics	(1)	11
stocks	(1)	4
subtract		1
sum		2
table		1
tables	(1)	1
taxes		1
teaching		2
ten		7
ten per cent		2
test		1
thirty-four		1
times		1
tithing		1
total		2
twenty		1
two		1
typewriter		1
value		1
verb		2
vitality		1
whole	(1)	1
x over one hundred		1
zero	(1)	2

28. CEREBELLUM.

Individuality Frequency, 53.

Failure Frequency, 2.

analysis		1
anatomy	(2)	9
ante bellum		1
backbone		1
balance		1
biology		1
body		2
brain	(63)	671
brains	(3)	13
brother		1
cauliflower		1
cerebral		3
cerebrum	(16)	127
cherub		1
circingle		1
coating		1
convolutions	(1)	1
coordination		1
cortex		1
cranium		3
dream		1
drug		1
drunk		1
earthworm		1
equilibrium	(1)	2
flower		1
folds		1
fossae		1
ganglion		1
G.		1
Golgi		1
gray		3
hair		1
head	(4)	44
hemispheres		1
hindbrain	(1)	3
involuntary		1
irritability	(1)	1
man	(1)	2
medicine		1
medulla	(1)	11
medulla oblongata		1
meningitis		1
mentality		1
model		1
motor		1
motor-nucleus	(1)	1
neck		1
newspaper		1
pain		1
physiology		14
picture	(1)	3
pigeon		1
pons	(1)	2
position		1
psychology		13
rabies		2
sensation		1
skull	(1)	6
small		1
S.		1
spinal		2
spinal cord	(1)	1
spine		1
Syracuse		1
term		1
text book		1
thought		2
tired		1
tract		1
ventricle		1
walnut-shaped		1
war	(1)	8
white		1
zoology		1

29. FRACTIONS.

Individuality Frequency, 91.

Failure Frequency, 3.

a/b		1	decimal	(9)	59	fractions		1	numerator	(2)	14	several		1
abominations		1	decimals	(13)	84	fractious		1	numerators		1	S.	(1)	1
addition		8	denomination		1	fracture		5	of		1	simple		1
additions		2	denominator	(1)	10	fractures		1	one-half	(2)	4	six		2
algebra		7	denominators		1	Grammar		1	one-quarter		2	small		1
algebraic		1	different		1	G.		1	one-third	(1)	1	split		1
arithmetic	(24)	267	difficulties	(1)	2	half		16	paper		2	stamp		1
banking	(1)	1	difficulty	(1)	5	halves		2	part	(3)	33	strokes		1
before	(1)	1	diffraction		1	improper	(1)	3	partial		2	study		1
bone		1	dislike		1	inch		1	particles		3	subtraction		1
bones	(1)	4	distillates		1	integer		3	partition		1	sums		4
book		1	distillation		2	integers	(1)	9	parts	(7)	54	symbol		1
boy		1	divide	(1)	3	integral		4	per cent		1	T.		1
blackboard		2	divided		2	integrals		1	percentage		18	teacher		1
break		1	division	(3)	19	interest		1	percentages		1	teaching		1
breakage	(1)	1	divisions		2	Jews		1	pieces		2	ten		1
breaking		3	dollar		1	line	(1)	8	picture	(1)	1	tenth		1
breaks		2	E.		1	lines		1	portion		1	three-fourths		6
broken		4	equations		1	mathematics	(2)	24	portions		3	three quarters		1
calculation	(2)	4	example		1	medicine		1	problem		1	trouble		1
cents	(1)	1	expectancy		1	misleading		1	problems		2	two		4
change		1	exponent		1	mixed		1	proper		1	two-thirds		4
character		1	faction		1	money		2	proportion		1	units		2
child		1	factors		1	multiplication		5	quotient	(1)	3	vulgar	(1)	5
children		1	figure		3	multiplier		2	ratio		2	whole		4
class		1	figures	(1)	23	multiplying		1	rational	(1)	2	whole number	(1)	3
common	(2)	19	figuring		1	nine-tenths		1	ratios		1	wholes		1
complex		1	five		1	nouns		1	reflection		1	words		1
compound		4	four		1	number	(5)	31	room		1	work		3
computation		1	fourth	(1)	1	numbers	(5)	55	school		14	Y.		1
computations		1	fraction		1	numerals		1	series		1	youth		1

30. TITRATION.

Individuality Frequency, 164.

Failure Frequency, (3) 254.

abstract		1	color	(2)	8	food		2	mortar		3	scratching		1
accuracy	(1)	1	concentration		3	force		1	motion		2	screen		1
acid		13	copper		1	four		2	music		1	sedimentation		1
acidity		2	corsets		1	friction		2	naturalization		1	separation		4
acids		2	crushing		1	funnel		1	neutralization		3	serum		1
action		1	cyclone		1	geology		4	nitrate		2	shaking		2
adding		1	decinormal	(1)	1	glass	(1)	1	nitration		1	simmer	(1)	1
addition		1	dehydrates		1	gravitation		1	nitrogen		1	solids		1
agar		1	dentition		1	Grecian		1	normality		1	solution	(1)	7
alkali		1	derivation		1	Greek		1	nutrition		3	spear		1
alkalinity		1	determination		3	grinding	(1)	3	obscure		1	stagnation		1
amusement		1	dictionary	(1)	3	grind up		1	permanganate		3	stirring		1
analysis	(4)	22	dietitian		1	gyration		1	pestle		1	stirring rod	(1)	1
antipodes		1	difficult		1	Harrison		1	pharmacy		1	stock		1
apparatus		2	difficulty		1	head		1	phenolphthalein		9	stretch		1
arbitration		1	digestion		1	health		1		(1)		striation		1
attrition		2	dilution	(1)	1	icicle		1	physics		7	subtraction		1
bacteriology		1	disaster		1	ignorance		2	physiology	(1)	3	surgery		2
baryta water		1	dislike		1	incomprehensible		1	pieces	(1)	1	tank		1
base		1	distil		1	indicator		7	pill		1	technical		1
beaker		4	distillation		1	infiltration		1	pills		1	teeth		1
biology		3	division		3	infusion		2	pink		2	term		1
blood		1	dripping		4	ipecac		1	pipette		1	test		1
book		1	drop		3	iron		2	pounding	(1)	1	testing	(1)	2
botany		1	dropping	(1)	1	laboratory	(3)	16	pour		1	tetanus		2
bottle		1	drops	(1)	4	Latin		1	pouring	(2)	2	tetrad		1
brain		1	drugs		2	laughter		1	powder		2	tetrahedron	(1)	1
Bunsen		1	drug store		1	leaves		1	precipitate	(1)	1	three		5
burette	(8)	57	drying		1	liquid	(1)	1	precipitation		2	tiara		1
calcium			dyadic		1	liquids	(1)	2	problem		1	tide		1
carbonate		1	ebullition	(1)	1	liquid solution		1	process		3	tight		8
calibration		1	end-point		1		(1)	1	proportions	(1)	1	tighten		2
calorimeter		1	energy		2	litmus	(1)	3	pulverization		1	tightening		1
chemical	(1)	5	enigma		1	maze		1	quantitative	(1)	1	tiles		1
chemical			estimation	(1)	1	measure		2	quantitative			tincture		1
laboratory	(1)	1	exhortation		1	measurement	(2)		analysis		1	tintillation		1
chemicals	(1)	1	experiment		2	measuring		3	quantity		1	tintinabulation		3
chemist		1	extraction		1	media		1	reaction	(1)	1		(1)	
chemistry	(25)	151	filter	(6)	14	median		1	red		2	tintulate		1
chemists		1	filtering		3	medicine		4	repetition		1	tirade		3
chew	(1)	1	filtration	(3)	18	methyl orange		2	rope		1	titan		1
churning		1	finely		1	mixing		4	rubbing	(1)	9	titanic		15
circle		1	flask		1	mixture	(1)	1	science		4	titanotherium		1
cock		1	fluid	(2)	2	mixtures		1	scintillation		1	T.		1

Titian		3
titillation		2
titivate		1
title		2
titrate		2
titric acid		1
titular		3
titulate		1
Titus		2
traction		1
trees		1
tremble		1
trembling		1
triad		1
triangle		1
trichina		1
trigonometry		1
trio		1
trite		2
tritonic		1
triturate	(1)	3
trituration		7
typewriter	(1)	7
typewriting		1
typhoid		1
tyrant		1
urinalysis		1
vessel		1
vibration	(1)	4
volume	(1)	2
volumetric	(1)	2
Wassermann		1
wasting		1
water	(1)	7
water analysis		1
wearing		3
wearing away		2
wiggle		1
word		4
work		1

31. CARBOHYDRATE.

Individuality Frequency, 103.

Failure Frequency, 1.

acetylene		2
acid		3
acids		1
albumen		1
alcohol	(1)	3
alimentary canal		1
analysis		1
anhydrous		1
antiseptic		1
Battle Creek		1
beans		1
benzene		1
biology	(1)	3
bitumen		1
blood		1
body		1
botany		2
bottle		1
bread		2
bubbles		1
cake		1
candy		1
capillary		1
carbolic	(1)	2
carbon	(5)	29
carbonate		3
carbon dioxide		2
carbonic		1
carbons		1
CH		3
chemical	(1)	21
chemistry	(9)	225
chickens		1
chloride		1
CHO	(1)	2
CHON		1
coal	(1)	5
combination		1
comet		1
compound	(2)	7
cooking		1
copper		1
corundum	(1)	1
dextrin		1
dextrose		2
diamonds		1
diet		1
dietetics		1
diets		1
digestion		2
dioxide		1
disinfectant		1
doctor		1
domestic science		1
drug		2
drugs		1
egg		3
electric		1
electric light		1
elements		1
emulsion		1
fat	(4)	38
fats		18
figures		1
fire		1
Fischer		1
fluid		1
food	(9)	89
foods	(1)	6
foodstuffs		1
formula	(1)	1
fruit		1
gas		6
gases		1
glucose		1
glycerin		1
G.		1
grease		1
H.		1
heat		2
H.		1
H2O		1
hydrocarbon	(4)	14
hydrocarbons		4
hydrochloric		1
hydrogen		1
hyposulphite		1
ignorance		1
inorganic		1
iron		1
K.		1
laboratory		3
lime		1
line		1
liquid		1
man		1
meat	(1)	1
medicine		4
metabolism	(1)	12
methane		1
methylene		1
mineral		1
misnomer		1
natural history		1
nitrogen	(2)	2
nitrogenous		1
not fat		1
nourishment		1
nutrition	(2)	5
organic	(1)	8
organic chemistry		2
organics		1
organism		1
oxide		1
oxygen		8
paraffins		1
pentosin		1
peroxide		1
photo-synthesis	(1)	2
physics		9
physiological chemistry		1
physiology		10
plant		2
plants	(1)	2
potato		1
potatoes		4
prescription		1
prestolite		1
proteid		20
proteids		3
protein	(1)	16
protoplasm		1
raffinose		1
ration		1
salt		2
salts		1
sewage		1
smell		1
soda		1
solids		1
S.		1
starch	(11)	66
starches		3
substance		2
sugar	(33)	170
sugars	(2)	17
sugary		1
sulphur		2
sulphuric acid		1
symbol		1
T.		1
teaching	(1)	1
T.		1
water	(1)	22
W.		1
zoology		1

32. DUODENUM.

Individuality Frequency, 91.

Failure Frequency, (1) 72.

abdomen		4
affection		1
alimentary canal		2
alimentation		1
anatomy	(7)	35
animal		2
anus	(1)	2
appendicitis		4
appendix	(1)	4
arch	(1)	1
arithmetic		3
assimilation	(1)	1
autopsy		1
belly	(1)	1
bend		1
bile	(1)	1
binding		1
biology		4
body	(2)	21
bone		1
book		6
botany		2
bowel	(1)	6
bowels	(2)	7
brain	(1)	21
bud		1
caecum		1
canal		1
caravan	(1)	1
cerebellum		1
chemistry		1
cloth		1
colon		8
constipation		1
cord		1
decimal		7
demon		1
deny		1
diaphragm		1
dictionary		1
die		1
digestion	(3)	19
digestive tract		1
doctor		2
doctors	(1)	1
dominoes		1
D.		1
double		4
dual	(1)	1
dualism		1
duel		2
duenna		1
D.		1
D.		1
duodecim		1
duodecimal	(2)	28
duo-decimals		2
duojeum		1
dwelling		1
D.		1
element		1
expression		1
extirpation		1
eye		1
feelers		1
first		1
food		1
fractions		1
gastric		1
geometry		1
gods		1
Greek		1
gut		3
head		3
history		3
hospital		1
human body		1
ileum	(2)	13
ill		1
insides		2
internal		2
intestinal	(1)	2
intestine	(64)	245
intestines	(1)	25
Italy		1
jejunum	(1)	18
Latin		29
lecture		1
liver		2
man	(1)	2
manikin		1
marriage		1
mathematics		3
medicine		2
medulla	(1)	1
membrane		2
mesentery		1
metal		1
millions		1
misbelieving		1
motion		1
music		2
number		4
numbers		5
octavo		1
oesophagus	(1)	4
operation	(1)	1
organ		1
organism		2
pancreas		2
peritoneum		1
peritonitis		1
physical		1
physiology	(8)	76
picture	(1)	2
pituitary body		1
polyhedron		1
portion		1
psychology		1
puzzle		1
pylorus		1
rectum		7
rhythm	(1)	1
ribs	(1)	1
Rome		1
sausage		1
science		4
septicaemia		1
skeleton		1
skin		8
sphincter	(1)	1
spinal cord	(1)	1
spleen	(1)	3
S.		1
stomach	(9)	85
structure		1
sweetbread		1
swelling		1
systems		1
teacher		1
ten		3
thousand		1
throat		1
tissue		1
tube		1
Turkish		1
twelve	(2)	13
twelve inches	(1)	1
twenty		1
two	(1)	47
two-ness		1
ulcer	(2)	7
Upper intestine	(1)	1
volume		1
wonder		1
word		1
years		1
zoology		2

33. COSECANT.

Individuality Frequency, 67.

Failure Frequency, (4) 44.

abbreviation		1
algebra	(1)	20
analytic		3
analytics		4
angle	(3)	10
angles		1
antecedent		1
arc		2
arithmetic	(1)	16
astronomy		2
awful		1
bisect		1
book		2
botanical		1
calculus		3
charts		1
chord		1
circle		5
coagulation		1
coalesce		1
coast		1
coefficient		7
cohesion		1
comparison		1
conic		1
consecutive		1
consequence		1
consequent		1
contrary		1
coordinate		1
cosine	(5)	36
cosines		1
cossack		1
cosy		1
cotangent	(2)	14
C.		1
curve		2
cut		2
cutting		2
D.		1
diagram		1
differential		1
digestive		1
division		1
drawing		1
E.		1
equal		1
fibres		1
follow		1
following		3
freshmen		1
function	(1)	2
geology		1
geometrical		2
geometry	(7)	79
grammar		3
great		1
happening		1
harvesting		1
hypothenuse	(1)	1
infinitive		1
Japanese		1
J.		1
Latin		2
line	(1)	10
lines		1
logarithm		1
logarithms	(1)	2
mathematics	(10)	66
measure		1
M.		1
navigation		2
numbers		2
P.		1
parenthesis		1
physics		2
problem		1
psychology		1
radical		1
radius		1
ratio		1
room		1
schoolroom	(1)	1
science		2
sea		1
secant	(10)	84
sector		1
segment		1
sequence		2
sextant		1
sine	(12)	46
song		1
square		1
tangent	(8)	68
text book		1
thought		1
together		3
triangue	(1)	8
trigonometry	(31)	369
truth		1
university		1
Warren		1
with		2
word		1

34. BIOLOGY.

Individuality Frequency, 146.

Failure Frequency, 3.

algae		1
all		1
A.		1
amoeba		9
analysis		1
anatomy		4
animal	(2)	35
animal life		1
anmials	(6)	41
anthrax		1
anthropology		2
astronomy		1
bacteria		2
bacteriology		3
B.		1
B.		1
B.		1
biographical		1
biography		4
biologist	(1)	1
biometric	(1)	1
biometry		1
bionomics		1
bios	(1)	1
bird		2
birds		2
bluff		1
bodies		1
body		4
bone		1
book	(2)	7
books		1
botany	(6)	71
B.		1
brains		1
brilliant		1
B.	(1)	2
B.		1
bug	(1)	2
bugs	(1)	37
building		3
B.		1
burn		1
C.		1
C.	(1)	1
C.		1
C.		1
cell		5
cells		1
chair		1
charts		1
chemistry	(2)	14
college		4
C.		10
course		1
courses		2
C.		2
crayfish		1
curriculum		1
Darwin		3
D.		1
D.		1
discipline	(1)	1
dissecting		1
dissection		2
doctor		1
doctorate	(1)	1
D.		1
duodenum		1
education		1
E.		1
embryology		2
entomology		1
environment		1
eugenics		3
evolution		3
experiments		1
father		1
fields		1
fish		1
fishes		1
flowers		1
food		1
force		1
frog	(4)	11
frogs		4
Galloway		1
G.		1
geology		7
God		1
G.		1
grub		1
H.		1
H.	(1)	2
Harvard		1
H.		1
high school		1
histology	(1)	2
history		2
H.		3
H.		2
Huxley	(2)	3
immoral		1
insect		1
insects		2
Institute of Technology		1
invertebrate		1
jarry		1
journalism		1
K.		1
labortory	(3)	38
L.		1
L.		1
life	(18)	159
Lilly Hall		1
limnology		1
living		1
lobster		1
L.		1
L.		1
L.		1
male and female		1
man		3
M.		1
medicine	(1)	3
menagerie		1
messy		1
M.		1
M.		1
microbes		1
mineralogy		2
M.		1
natural history		1
nature		1
neurology		2
note book		1
ontology		1
organic		1
organism		3
organisms		1
origin of life		1
outdoors		1
Owen Hall	(1)	1
oyster		1
palaeontology		1
parasitology		1
P.		2
P.		1
people		1
P.		1
physics		6
physiography		1
physiology	(1)	22
plant	(1)	8
plants	(2)	13
pleasure		1
P.		1
P.		1
profession	(1)	1
professor		1
protozoa		2
protozoology		1
protozoon		1
psychology	(1)	6
public health	(1)	1
rabbit		1
R.		2
R.		1
R.		1
R.		1
S.		1
school		2
science	(12)	116
science of life		1
scientific	(1)	1
scum		1
S.	(1)	2
sign		1
sister		2
skeleton		2
S.		1
Snow Hall	(1)	1
S.		1
S.		1
starfish		2
S.		1
still		1
S.		1
stones		1
student		1
study	(1)	26
teacher		2
teaching		3
test		1
test tube	(1)	1
theorem		1
thought		1
T.		1
T.		1
trigonometry		1
triology		2
T.		1
two		1
university		1
vital		1
W.	(2)	2
W.		1
W.		1
W.		1
W.		2
Woods Hole		1
work	(1)	1
worm		1
worms		3
zoology	(15)	92

35. ODYSSEY.

Individuality Frequency, 51.

Failure Frequency, 1.

Achilles		1
adventure		1
Aeneid		4
analysis		1
ancient		1
audacity		1
boldness		1
book	(1)	14
classics	(2)	6
college		1
dictionary		1
eccentric		1
English		2
epic		2
fable		1
flight		1
geography		2
G.		1
Greece	(1)	17
Greek	(11)	119
Greek history		1
Greeks		3
Helen		1
history	(1)	3
Homer	(52)	455
Horace	(1)	2
humiliation		1
Iliad	(18)	197
L.		1
language		1
Latin		17
literature	(2)	14
model		1
M.		1
myth		2
mythology		1
Nausicaa		1
oddity		1
ode		1
Odysseus	(1)	6
oracular		1
P.		1
P.		1
peculiar		1
peculiarity		1
Penelope		1
period		1
pictures		1
pleasure		1
poem	(2)	11
poetry	(1)	10
Pope		2
pyramid		1
recitation		1
R.		1
Roman		2
school		1
sea		1
ship		1
shore		1
sirens		1
stars		1
statue		1
story		1
study		1
surge	(1)	1
teaching		2
translation		1
travel	(1)	1
Troy		1
Ulysses	(4)	49
Virgil		7
wandering	(1)	1
wanderings		1
wars		1

36. VERTEBRATE.

Individuality Frequency, 68.

Failure Frequency, 0.

amphibian		1
amphibious		1
amphioxus		2
anatomy	(6)	26
animal	(27)	204
animals	(3)	27
anthology		1
anthropology		1
ape		1
articulate		1
back	(2)	13
backbone	(15)	103
bear		1
beast		1
B.		1
biology	(1)	16
bird		1
birds		1
body		3
bone	(2)	43
bones	(1)	25
brain		7
cat	(1)	8
cervical		1
chimpanzee		1
chorda		1
chordate	(1)	3
class	(1)	1
classification	(1)	1
coelenterata		1
column		8
conundrum		1
cord		1
cow		4
cripple		1
crooked		1
Darwin		1
dinosaur		1
dog		3
earthworm		1
E.		1
elephant		2
erect		2
evolution		4
fertile		1
fish	(2)	14
force		1
fossil		2
frog		4
geology	(1)	2
giraffe		1
Haeckel		2
H.		1
higher animal		1
higher animals		1
horse		8
Huxley		1
invertebrate	(15)	104
invertebrates		1
jelly		1
jointed		1
joints		1
kingdom	(1)	2
laboratory		1
legs		1
life		2
lizard		1
mammal	(1)	31
mammalia		1
mammals		5
man	(3)	66
matter		1
medicine		1
mollusc		1
monkey		1
morphology		1
museum		1
non-vertebrate		2
notochord		2
ornithology		1
O.		1
palaeontologist		1
paleontology		2
P.		1
physiology		12
psychology		1
quadruped		1
reptile		1
rib		1
science		1
segment		1
skeleton	(3)	27
skeletons		1
skull		2
snake		4
species		1
specimen	(1)	2
spinal	(3)	17
spinal column	(1)	4
spinal cord		1
spine	(2)	58
spineless		1
spines		2
structure		3
tail		1
verify		1
vertebra	(1)	3
vertebrae		4
vertigo		1
whale		1
W.		1
Woods Hole	(1)	1
worm		1
zoo		1
zoology	(4)	43

37. GRAVIMETRIC.

Individuality Frequency, 101.

Failure Frequency, 53.

analysis	(12)	52
analytic		1
analytical		1
anthropometric		1
apparatus		1
apple		1
arithmetic		3
arithmetical		1
attraction		3
A.		1
avoirdupois		1
balance	(4)	16
balances		1
ball		1
barometer		1
biometric		1
burette	(1)	1
by weight		1
calcium oxide		1
centrifugal		1
charge		1
chemistry	(5)	35
circle		1
compass	(1)	1
composition		1
declension		1
determination	(1)	4
determinations		1
diagrams		1
diametric		2
dictionary		3
difficulty		1
down		1
draw		1
drawing	(1)	1
dynamics		1
earth		7
ebullition	(1)	1
electricity		1
elevator		1
energy		1
engineering		2
esoteric		1
fall		2
falling		1
falling body		1
figuration		1
flask		2
fluid	(1)	1
force		6
France	(1)	1
French		1
function		1
g.		1
galvanometer		4
geocentric		1
geography		3
geology	(1)	2
geometric		4
geometry		6
geophysical		1
glass	(1)	1
gram		1
graph		2
graphic		1
graphophone		4
graphs	(1)	1
grave	(1)	2
gravel		1
graven		1
gravimeter		1
gravinometer		1
gravitate		3
gravitation	(4)	31
gravity	(1)	94
gravy		1
heavy	(5)	18
hydraulic		1
hydrolysis		1
hydrometer		2
instrument		4
instruments		1
isomeric		1
isometric		3
laboratory		2
land		1
Latin		2
law		1
lead		1
line		1
lines		1
liquid	(1)	1
machine	(1)	2
mathematics	(1)	7
measure	(4)	63
measured		2
measurement	(3)	34
measurements		5
measure of weight		2
measuring		10
mechanic		1
medical		1
mensuration	(1)	2
metals		1
meter		8
meters		1
method	(3)	4
metric		10
metrical		1
metric system		8
metrocentric		1
metronome		1
mining		1
monument		1
Newton	(1)	16
number		1
optometry		1
pedestrian		1
philology		1
phonograph		1
physics	(6)	99
physiography		1
pictorial		1
picture		1
platinum		1
plumb		1
pressure		2
procedure		1
process		2
psychology		1
psychometric	(1)	1
pull		2
pycnometer		1
quantitative		2
rule		1
ruler		2
scale	(1)	11
scales	(2)	5
school		1
science		15
separation		1
solution		1
specific		2
specific gravity		2
spring balance		1
star		1
stoichiometric		1
sure		1

surveying 1
system (1) 24
table 2
tape measure 1
technology 1
test (1) 3
tests 1
titration 4
trigonometric 1
tropism (2) 2
unit 1
volume 1
volumetric (7) 42
water 1
weigh 2
weighing (8) 14
weight (12) 103
weight measure 3
weights (2) 7

38. FEDERAL.

Individuality Frequency, 74.

Failure Frequency, 1.

aid 1
Alexander Hamilton 1
America 1
American 1
annex 1
anti-federal 1
army 19
assembly 1
athletic 1
Australia 1
bank 2
baseball (2) 5
battle 1
blue-coat 1
board (1) 3
book 1
building 2
bureau 1
capital 2
chief 1
civics 1
civil 5
Civil War 3
colonial 1
combine 1
combined (1) 1
commission 1
commonwealth 1
Confederacy 2
confederate (9) 43
confederates 1
confederation 1
congress (2) 2
constitution (7) 47
constitutional (1) 6
constitutionalist 2
constitutionalists 1
continental 1
control (1) 3
council 1
country 8
court (1) 9
courts (2) 5
delivery 1
democratic 2
district 2
dominion 1
express 10
federation 1
ferocious 1
feudal 1
flag 1
fusion 1
government (33) 353
governmental 3
governor 1
grant (1) 2
Hamilton 4
hat 1
history 5
Huerta 1
inquiry 1
insurance 1
insurgent 1
interstate commerce 1
investigation 1
Jefferson (1) 2
judge 5
jurisdiction 1
law (1) 15
laws (1) 1
league 13
Lee 1
liberal 2
Madison 1
Mexican 1
Mexicans 1
Mexico 10
military 1
monarchy 1
money 3
municipal 5
nation 6
national (2) 33
national government 1
navy 1
New York 1
north 1
northern 1
obligation 1
papers 1
Philadelphia 1
politics (2) 3
postal 1
prison 2
rational 1
rebel (1) 10
rebels 4
republic 2
republican (1) 3
reserve 5
reserve act 1
revolution 2
soldier (2) 11
soldiers (1) 4
south 2
southern 1
southerner 1
state (10) 80
state rights 1
states (2) 20
statute 1
street (1) 1
sugar 1
Switzerland 1
system 2
tax (1) 3
tires 1
town 1
troop 1
troops (2) 13
truck 1
union (2) 39
unionist 1
united (1) 6
United States (7) 41
United States government 1
unity 1
vocal 1
war 15
Washington (1) 12
Wilson 3

39. MORPHOLOGY.

Individuality Frequency, 130.

Failure Frequency, (1) 31.

ablant 1
abnormal 1
abnormalism 1
algae 1
A. 1
amorphous 3
analysis 2
anatomy (9) 31
ancient 1
angiosperma 1
animal (1) 9
animals (1) 5
anthology 1
anthropology 10
anthropomorphic 1
anthropomorphism 2
arena 1
bacteria 3
bacteriology 3
biological 1
biology (3) 44
blood (1) 2
bodies (1) 2
body 5
bone 2
bones 4
book (1) 5
botany (6) 33
brain 1
bugs 1
butterflies 1
butterfly 3
Canadian 1
cat 2
catalogue 1
cell 1
cells 1
change 35
changes 3
characteristics 2
chemistry (1) 3
classification 3
coast-line 1
cocaine 1
cocoon 1
college 1
comparative 1
constitution 1
corpse (1) 1
C. 1
crystal 1
crystals (1) 1
cytology 1
dead 4
dead body 1
death 48
death rate 1
degenerate 1
derivation 2
development 4
dictionary 1
disease 4
doctor 1
doctors 1
doxology 1
drugs 1
dying 1
ease 1
ecology (1) 2
embryo 1
embryology (2) 10
endosperms 1
eternity 1
ethnology 1
etiology 1
etymology 1
evolution (1) 2
exchange 1
experimental 1
fashion (1) 1
fern (1) 1
field 1
fitness 1
flower 3
flowers (1) 2
form (59) 131
forms (2) 10
form study 1
fossils 1
function (1) 2
fungi 1
geology 4
Greek 2
growing 1
growth 1
gymnosperms 1
Haeckel 1
head 1
health 1
heart 1
H. 1
hermaphrodite 1
histology 14
history 1
homology 1
hospital 2
human 1
H. 1
Huxley 1
hygiene 1
illustrations 1
infancy 1
insect 1
insects 2
J. 1
knowledge 1
laboratory (1) 2
language 1
leaf 1
life 7
logic 2
logos 1
man 6
M. 1
medical 1
medicine (1) 18
metamorphosis 3
microscope 5
microscopic 1
minute 1
mollusc 1
morgue (1) 1
Mormon 1
morphe 1
Morpheus 8
morphine (3) 31
morphosis 1
mortality 1
mortification 1
moth 1
mouldy 1
mythology 2
N. 1
origin 1
ornithology 1
ossify 1
paleontology (1) 2
parts 1
pathology 6
person 1
philosophy 1
physics 1
physiology (6) 27
plant (1) 26
plants (5) 27
poison 1
psychology 1
roots 1
science (4) 59
sex 1
shape (3) 26
shapes (1) 2
sick 1
sickness 1
sickness 1
similar 1
size 1
skeleton 2
sleep 20
species 1
S. 1
stone 1
straight 1
S. 1
structural (1) 1
structure (6) 52
studies 1
study 14
study of plants 1
substance 1
sulphur 1
surface 1
system (1) 2
taxonomy 1
teacher 1
teleology (1) 1
T. 1
tissue 1
toxicology 1
trees 1
undertaker 1
variation 3
vertebrate 1
vertebrates 1
weakness 1
W. 1
word 2
words 1
writer 1
zoology (2) 20

40. HYPOTHENUSE.

Individuality Frequency, 55.

Failure Frequency, 6.

abscissa		2
algebra		1
altitude		1
angle	(8)	55
angles		6
animal		1
Aristotle		1
arithmetic		8
arm		1
axiom		1
base	(2)	14
cathete		1
circle		1
conclusion		1
cosine		1
crooked		1
demonstration		1
diagonal	(1)	6
diagram		1
distance	(1)	1
Euclid	(1)	1
expression		1
father		1
figure		1
figures		1
formula		1
geology		1
geometry	(9)	141
grammar		1
hippopotamus		2
horizontal		1
hyperbola		3
hypocrite		1
hypostoma		1
hypothecate		1
hypothesis	(1)	7
incline		1
isosceles		1
J.		1
leg	(2)	20
legs		3
letter N.	(1)	1
line	(2)	24
long		1
mathematics	(2)	19
misery		1
news		1
oblique		1
π		1
perpendicular	(1)	6
Plato		1
pons asinorum		2
problem		1
proposition	(1)	2
Pythagoras	(1)	11
Pythagorean proposition		1
reasoning		1
rectangle		5
right		5
right angle	(1)	15
right angled triangle		1
right triangle		2
secant	(1)	2
section		1
shortness		1
side		8
sides		1
sine		1
slant		2
slope		1
Socrates		1
square		13
squares		3
straight line		1
subtending	(1)	1
sun		1
supposition		1
tangent		3
theory		1
triangle	(61)	542
triangles		1
triangulation		1
trigonometry	(2)	8
upright		1
visual	(1)	1

41. MAGELLAN.

Individuality Frequency, 47.

Failure Frequency, (1) 7.

Africa		1
America	(1)	7
Argentine		1
astronomy		1
Balboa		2
biology		1
boat		1
brain		1
British		1
cape		5
Cape Horn		7
captain		1
circumnavigate		2
circumnavigation		13
circumnavigator		2
city		2
civil		1
Columbus	(1)	4
combers	(1)	1
compass		1
Cook	(1)	1
Cortez		1
cruise		1
Darwin	(1)	1
date		1
Diaz		1
discoverer	(3)	37
discoverers		1
discovery	(1)	22
earth		1
exploration	(1)	5
explorer	(3)	37
Ferdinand		1
flagella		1
flagellum		1
general		1
geography	(2)	19
Gibraltar		1
globe		1
history	(1)	28
Indus		1
island		4
Italian		1
Keats		1
Labrador	(1)	1
land		1
Magella	(1)	2
magician		1
man		10
map		1
inarticulate		1
name		1
navigation		3
navigator	(1)	4
ocean	(2)	8
Pacific	(1)	11
Panama		3
passage		1
Patagonia		1
Patagonian		1
Philippine	(1)	1
picture		2
Portugal	(1)	1
Portuguese	(1)	2
sail		1
sailor		4
schooner		1
scientist		1
sea		10
sea-farer	(1)	1
ship		5
South America	(2)	23
Spain	(1)	13
Spaniard		3
Spanish		4
strait	(17)	269
straits	(52)	344
Straits of Magellan		1
Tierra del Fuego	(1)	2
time		1
travel		2
traveler		2
trip		1
voyage		9
war		2
water		5
world		8
word		1

42. HEXAMETER.

Individuality Frequency, 73.

Failure Frequency, 6.

Aeneid	(1)	4
air		1
algebra	(1)	3
angle		2
apothem		1
apparatus	(1)	2
arithmetic		3
bees		1
bicycle		1
Blackie	(1)	1
caesura		1
cell		1
centimeter		1
circle		4
circumference		1
crystal		2
dactyl	(1)	4
dactylic		5
decimal		1
declamation	(1)	1
diagonal		2
diagram		1
diagrams		1
diameter	(3)	14
distance		1
double		1
drawing		2
duodecagon		1
edge		1
eight		2
English		3
epic		2
Euclid		1
Evangeline	(1)	4
examination	(1)	1
example		1
feet		1
figure	(4)	53
five		1
foot		2
form	(1)	10
fraction		1
geology		1
geometric		2
geometry	(3)	100
Greek		5
Greeks		1
hectagon		2
Hector		3
heptateuch		1
hexagon	(1)	21
hexagonal		3
hexagraph		1
H.		1
Homer	(1)	14
honeycomb		1
horoscope		1
horse		1
iambic		11
iameter		1
Iliad	(2)	3
instrument		6
kindergarten		1
language		1
Latin		3
line		5
literature		2
Longfellow		4
Longfellow's Miles Standish		1
many sides		1
mathematical		1
mathematics	(1)	18
measure	(1)	9
measurement		5
meter	(2)	19
metric	(1)	4
miles		1
Milton		1
music		8
N.		1
noun		1
octagon	(1)	8
octagonal		2
Odyssey	(1)	3
paper		1
parabola	(1)	2
parameter		4
Paris		1
parsing		1
pentad		1
pentagon		4
pentagonal		1
pentameter	(4)	59
perimeter		16
physics		2
plane		1
poem	(4)	9
poetry	(20)	116
polygon	(2)	20
polyhedron		1
Pope	(1)	4
prism		1
problem		1
prose	(2)	2
prosody	(1)	5
pyramid		1
quintameter		1
rhetoric		2
rhomboid		1
rhomboidal		1
rhyme		4
rhythm	(1)	6
rule		1
S.		1
scanning		1
scansion		2
school		1
science		2
seven		1
shape	(1)	3
side		1
sides		4
six	(5)	121
six angles		1
six foot		2
six parts		1
six-sided		3
six sides		1
solid		1
Spenser		1
spiders	(1)	1
square		2
stanza		2
steigt		1
studying		1
taximeter		1
teach		1
teaching		1
ten		1
tetrameter	(1)	6
triangle	(1)	9
trigonometry		6
T.		1
verse	(16)	103
versification		2
Virgil	(4)	16

43. METEOR.

Individuality Frequency, 100.

Failure Frequency, 0.

aerolite		1
air		2
airship		1
Alaska		1
American Museum		1
arctic		1
asteroid		4
astrology		1
astronomy	(10)	125
bacteriology		1
ball	(1)	1
ball of fire		1
black		1
blood		1
body	(1)	5
bright	(1)	3
brightness		2
brilliancy		1
brilliant		1
Brooklyn		1
career		2
celestial		1
cheese		1
cloud		1
comet	(8)	89
comets		1
cosmic		2
destruction		1
discovery		1
discussion		1
D.		1
earth		1
elements		1
etching		1
explosion		1
fall	(2)	9
falling		14
falling star		3
famous		1
fast		1
fear		1
fell		1
fiery		1
fire		6
fire ball		1
flame		2
flare	(1)	1
flash		11
flashing body		1
flight	(1)	3
fly		1
flying		2
fragment		1
geologic		1
geology		7
Greek		1
Halley		1
Halley's		2
Halley's comet		1
Harpswich		1
heat		1
heaven	(1)	3
heavenly		1
heavenly body		1
heavens	(1)	13
Helmholtz		1
Hohenzollern		1
hot		1
image	(1)	1
Iowa		1
iron	(6)	31
K.	(1)	1
laboratory		1
lava		1
light	(2)	32
lightning		1
local		1
mass		1
measure		2
mellifluous		1
message		1
metal	(1)	6
meteorite	(5)	15
meteorites		1
meteorlogical		1
meteorology		3
meter	(1)	1
middle		1
Milton		1
mineral	(1)	2
mistake		1
moon		1
motion		2
museum	(1)	8
Nebraska		1
nebula		1
newspaper		1
nickel		3
object		1
Peary		1
Perseids		1
phenomenon		1
picture		1
planet		14
planetesimal	(1)	1
planets		3
poem		1
poetry		1
quick		1
rapid		1
road		1
rock	(1)	7
rocket		2
rush		1
satellite		2
Saturn	(1)	1
science		1
ship	(1)	1
shooting		3
shotting	(1)	4
shooting star	(3)	5
shooting stars		1
shower	(1)	1
sky	(10)	112
space		1
sparks		1
spectrum		1
speed		1
star	(29)	275
stars	(1)	31
stella		1
stone	(2)	16
streak		2
sun		1
surprise	(1)	1
swiftness		1
tail		2
task		1
telegraphy		1
telescope		1
trail	(1)	2
train	(1)	2
water		3
wave		1
weather		1
weight		1
Wilhelm		1
world		1
yacht		2

44. MOMENTUM.

Individuality Frequency, 64.

Failure Frequency, 0.

acceleration		8
accident		1
action		3
arithmetic		1
automobile		3
balance		1
ball	(3)	6
body		6
bullet		1
bump		1
cannon		1
cannon ball		2
car		2
cause		1
center		1
circumference		1
down		1
drop		1
eccentric		1
energy	(3)	10
engine	(1)	7
equation		1
factor		1
fall		2
falling		1
fast		1
flying		1
force	(17)	223
formula		2
forward	(1)	1
go		1
going	(1)	4
gravimetric		1
gravitation		1
gravity	(4)	13
heavy		3
hurry		1
immobility		1
impact	(2)	4
impetus		8
impulse	(1)	6
increased		1
inertia	(7)	43
initiative		1
irresistible		1
irresistibility	(2)	1
I. W.		1
kinetic energy	(2)	2
law		1
laziness		1
leg		1
locomotive		1
machine		1
mass	(5)	38
matter		1
mechanics	(2)	11
mesentery		1
minimum		1
minute		1
moment		4
momentous	(1)	2
momentum		1
morality		1
motility		1
motion	(9)	76
mountain		1
movement	(4)	36
moving		2
m. v.	(1)	6
Newton		3
object		1
ocean		2
pendulum		2
physics	(8)	104
plane		1
power		15
present		1
pressure		2
prodigious		1
projectile		1
push	(2)	13
quick		2
quickness		1
rapid		1
rapidity		4
rate		1
resistance	(1)	2
rest	(1)	1
roll		1
rolling		1
rush		2
rushing		1
science		1
ship	(1)	1
shoot		1
sliding		1
space		2
speed	(9)	149
sphere		1
start		2
still		1
stone		1
strength		1
swift		5
time		1
train		20
trolley		1
truck		1
velocity	(5)	36
vis viva	(2)	2
weight	(7)	37

45. CORNWALLIS.

Individuality Frequency, 70.

Failure Frequency, 3.

admiral (1) 1
ambassador (1) 1
America 2
American 1
American history 1
A. 1
army 3
battle (4) 57
battles 1
Boston 2
Brandywine 1
British (1) 18
brook 1
Burgoyne (1) 7
charge 1
Civil War 2
coal 1
Columbus 1
commander 1
C. 1
corn 1
corn-cob 1
cornucopia 1
Cornwall (2) 7
country 1
Cromwell 1
defeat 11
defeated 1
duke (2) 6
Edinburgh 1
E. 1
England (2) 45
English (1) 36
Englishman 2
fight 4
fighter 1
fighting 1
French 1
general (11) 130
generals 1
geography (1) 1
Georgetown (1) 2
George Washington 3
giant 1
government (1) 2
Great Britain 1
history (2) 36
Hudson (1) 4
Hudson River 1
India (1) 2
Indians 1
Ireland 2
J. 1
Jackson 1
Jamestown 1
J. 1
J. 1
L. 1
Lafayette 3
leader 1
lodge 3
Long Island 1
lord (7) 41
man (3) 19
New Jersey (1) 1
New York 3
night 1
Oregon (1) 1
painting 1
palisades 1
peace (1) 1
Peekskill 1
Pennsylvania 1
picture 3
pictures 1
place 1
plains 1
Quebec 1
rebellion 1
red 2
red-coat 1
revolution (9) 80
revolutionary 3
Revolutionary War 3
Richmond 1
Saint Nicholas 1
Saratoga 4
Scotland 1
siege (1) 1
snow 1
soldier 11
soldiers 1
statesman 1
surrender (7) 49
surrendered 1
sword 4
Syracuse 1
T. 1
teacher 1
Texas 1
threatening (1) 1
Ticonderoga 1
troops 1
uniform 1
valley 2
Valley Forge 2
Wales 1
war (1) 25
Washington (4) 75
Waterloo 3
West (5) 35
York (1) 7
Yorktown (25) 167
Yorktown Heights 1

46. PROTOZOON.

Individuality Frequency, 121.

Failure Frequency, 14.

acinetae 1
age 6
algae 1
amoeba (27) 187
amoeban 1
ameboid 1
amphibian 1
anatomy 1
ancient 2
ancient animal 1
animal (14) 107
animalcule (2) 10
animal parasite 1
animals 3
antiquity 1
anything (1) 1
archaic 1
atomic 1
bacteria (2) 7
bacteriology 6
beginning 1
biology (4) 135
bioplasm 1
blood 1
blue 1
body 1
botany 4
B. 1
bryophyte 1
bryozoon 1
bug (1) 9
bugs 2
B. 1
C. (1) 4
carbohydrates 1
carbon 1
cell (2) 20
changing 1
chaos 1
chart 1
chemistry 3
cilia 1
class (1) 2
college 1
creation 1
creature 1
crustacean 2
Darwin (1) 2
deep sea 1
D. 1
difflugia 1
digestion 1
disease (1) 4
diseases 1
early 2
E. 1
elemental 1
elementary 1
embryology 1
entozoon 1
eras 1
Euglena 1
evolution 3
fertilization 1
first 10
first life 1
flagellate 4
fluid 1
food 6
form 1
foraminifera 1
geology 20
germ 3
G. 1
God 1
G. 1
green 1
group 1
Haeckel 2
H. 1
high school 1
hydra (1) 2
hydrate 1
hydrozoon 1
hygiene 1
infection 1
infusion (1) 1
infusoria 5
insect 1
invertebrate 1
jelly 3
J. (2) 2
lakes 1
Latin 1
Leishman-Donovan 1
life (3) 36
lifeless 1
low 1
lowest 1
mammal 1
marine (1) 1
metazoa 2
metazoon (4) 18
microorganism 5
microscope 5
microscopic (1) 3
minute 2
mollusc 1
motion 1
movement (1) 1
nuclein 1
O. 1
one cell 2
organism 6
organisms 1
ovum 1
paleontology 2
paramoecium (6) 16
parasite 7
pedagogy 1
period 2
periods 1
phyla 1
phylum 1
physiology 9
P. 1
plant 7
plasm 1
prevital 1
primal 1
primitive (3) 10
prodigy 1
proletariat 1
protagonist 1
protegulum 1
proteid 2
protein 1
proteus 1
protista 2
protophyte 1
protoplasm (3) 17
protoplasmic 1
protose 1
protozoa 1
protozooid 1
psychology 1
pulp 1
rock 1
science 12
S. 1
sea (1) 4
sea shore 1
seed 1
semen 1
sewage 1
simple (1) 3
simplicity 1
single 2
slime 1
small (1) 7
smallness 1
S. 1
specimen 1
sperm 1
spermatozoon 1
sponge 1
sporozoon 1
stone 1
S. 1
study 1
stuff 1
text book 1
unicellular (6) 14
Urtiere 1
vagina 1
vegetable 1
water 11
wiggle 1
zone 3
zoology (8) 79

47. SYNTAX.

Individuality Frequency, 67.

Failure Frequency, 3.

adverb		2
agreement		1
algebra		1
analysis	(1)	6
analyze		6
Anglo-Saxon		1
arithmetic		2
arrangement	(1)	3
beauty		1
book		1
botany		1
Cinderalla		1
class		1
classification		1
classroom		1
climax	(1)	1
combination		1
composition		3
concept		1
conjugation	(1)	3
connection		1
construction		19
context		1
correctly		1
declension		7
diagram		2
diagrams	(1)	1
diction		1
division		1
doctor	(1)	8
English		19
English grammar		1
form		2
French		1
genealogy		1
German		1
grammar	(57)	577
grammatical	(1)	2
Greek	(2)	4
hard		1
instruction		1
labor		1
language	(1)	14
Latin		12
L.		1
logic		1
mathematics		3
M.		1
meaning		1
M.		1
noun	(1)	19
nouns		4
nuisance		1
numbers		1
of		1
parse	(1)	4
parsing		3
participle		1
phrase		1
plates		1
play		1
predicate	(1)	2
preface		1
pronoun		1
prosody	(7)	27
pupils		1
question		1
reflex		1
regents		2
relation		3
relationship		1
rhetoric	(3)	21
rule		2
rules		3
sailor		1
school		4
schoolroom		1
science	(1)	1
sentence	(5)	42
similar		1
S.		1
speech	(1)	3
spelling		1
structure	(1)	7
study		2
subject		1
S.		1
syncopate		1
syndicate		1
synonymous		1
synthesis		7
synthetic		2
system		1
tax	(1)	3
technical		1
tin tacks	(1)	1
together		1
use		1
verb	(7)	49
verbs	(1)	8
verse		1
Virgil		1
word	(1)	11
words	(1)	8
work		1
writing		1
Wundt		1
Xenophon		1
yawning		1

48. DISTILLATION.

Individuality Frequency, 91.

Failure Frequency, 2.

alcohol	(9)	77
ammonia		2
analysis		1
apparatus		5
atmosphere		1
beaker	(1)	1
beer		5
blood	(1)	1
boil		3
boiler	(1)	1
boiling	(5)	13
booze		1
bottle	(1)	5
Bourbon		1
brandy		2
brewery	(1)	11
brewing		2
bromide		1
carboy		1
cell		1
change		1
chemical		2
chemistry	(8)	96
cider		2
clear		1
coagulation	(1)	2
coffee		1
coil		1
concentration		1
condensation	(3)	10
condenser	(1)	4
constellation		1
contraction		1
cremation		1
crystallization		1
destructive		1
dew		9
dilation		1
distance		1
distant		1
distend		1
distil		5
distillate	(2)	2
distilled		2
distillery		6
distilling	(1)	2
drink		1
drinking		1
drop		2
drops	(1)	4
drug store		1
drying		1
ebullition	(1)	1
electricity		1
enlarge		1
essence		2
ether		1
evaporation	(5)	18
exhalation		3
expanding		2
expansion		1
experiment		3
extend		1
extension		2
extract		1
eyes		1
fermentation		2
fever		1
filter	(1)	8
filter paper		1
filtration		3
flask	(1)	12
fluid		3
fluids		2
fraction		3
fractional	(1)	15
fractionating		1
fractionation	(1)	2
gas		3
heat		7
heart		1
H_2O		1
hydraulic		1
improvement	(1)	1
inflated		1
inhalation	(1)	1
instillation		1
Kentucky		1
laboratory	(2)	3
line		1
liquid	(2)	12
liquidation		1
liquids		5
liquification		1
liquor	(1)	32
liquors		6
M.		2
medicine		1
mercury		1
moonshine		1
oil		1
oils		1
percentage		1
percolation		1
physics		9
pouring		1
precipitate		1
pressure		1
pressures		1
process		7
product		1
professor		1
proximity		1
pure		3
purification	(1)	10
purify		5
purifying		2
purity	(1)	4
reduction		2
refining		1
research	(1)	1
retort	(1)	10
rye		1
science		2
separating		1
separation		5
sifting		1
sight		1
solution		3
spelling		1
spirits		11
stars		2
steam	(2)	21
still	(2)	10
sublimation	(1)	1
sugar		1
sulphuric		1
superior		1
swamp		1
swelling		1
swollen		1
temperature		1
titration	(1)	1
tube		2
tubes		1
vacuum		1
vapor	(5)	12
vaporization		1
vaporize		1
volatility		1
volatilization		1
volume		1
water	(20)	258
whiskey	(11)	98
wine		8
wines		1
work		1
worm		1
yeasts	(1)	1

49. POLLEN.

Individuality Frequency, 54.

Failure Frequency, 4.

anther	(4)	11
anthers		1
Apollum		1
bee	(3)	32
bees		16
beeswax		1
Belguim	(1)	1
biology		2
botany	(6)	73
bumble bee		1
butterfly		1
Campbell		1
carrying		1
college		1
color		1
C.		1
core		1
corn		8
corn pollen		1
cross fertilization		1
daffodils		1
dust	(3)	17
Dutch		1
fecundation		1
fertility		1
fertilization	(4)	16
fertilize		1
fish		1
flower	(36)	419
flowers	(4)	99
garden		1
germination		1
gold		1
grain	(1)	12
grains		3
granules		1
Greek		1
hay fever	(1)	5
Holland		1
honey		3
insect		1
insects	(1)	4
leaf		1
life		1
lily		3
lycopodium		1
male		2
M.		1
ovule	(1)	3
pallial		1
paper		1
petals		1
picture		1
pistil		6
plant	(18)	82
plantago		1
plants	(3)	23
Poland		2
polyandry		2
pool		1
poppy		2
powder	(1)	12
reproduction		3
return		1
rhododendrons	(1)	1
rose		1
scatter		1
seed	(2)	14
semen	(1)	2
serum		1
smell	(1)	1
soft		1
sperm		1
spore		1
spring	(1)	2
sprout		1
stamen	(3)	27
stamens		2
stigma	(1)	9
tassel		1
tube	(2)	5
vegetation		1
water		2
weeds		1
wheat		1
wind		1
yellow		18
yellow dust		2
yellow powder	(1)	1

50. PENINSULA.

Individuality Frequency, 68.

Failure Frequency, 3.

Alaska		1
America		1
amoena	(1)	1
arm		1
bay	(1)	5
body of land		1
boot		1
California		1
campaign		5
cape	(4)	35
Cape Cod	(1)	6
Cape Horn		1
Chesapeake		1
connection		1
continent	(1)	3
Corea		1
Cornwall		1
country		2
Crimea		1
delightful		1
Denmark		2
description	(1)	1
diagram		1
dirt		1
Dover		1
estuary		1
extension		2
Florida	(6)	64
form		2
Gallipoli		1
geography	(10)	128
German		1
Gibraltar		2
Good Hope		1
Greece		3
gulf		2
headland		1
Iberian	(1)	4
island	(25)	210
isthmus	(2)	22
Italy	(3)	18
Jamestown		1
jutting		1
Kiau-Chow		1
Korea		1
Labrador		2
land	(14)	172
land forms		1
Leland Stanford		1
Lower California		1
Madagascar		1
Magellan		2
mainland		1
Malay	(1)	4
map	(2)	16
Massachusetts		1
Mexican		1
Mexico		1
Michigan	(1)	9
milk		1
Miseno		1
narrow		2
neck	(2)	19
neck of land	(1)	1
New York	(1)	1
Norway		1
ocean	(1)	8
Ohio		1
oriental		1
Panama		10
paper		1
pen		1
peninsula		1
penning		1
Pennsylvania		1
physical geography		1
physiography		1
point	(2)	17
point of land		1
Portugal		2
projection		6
river		1
Sagamore		1
sand		1
San Francisco		1
San Mateo		1
Scandinavia		3
sea	(1)	9
shape	(1)	2
sharp		1
Sinai	(1)	1
sound		1
south		1
South America		2
Southern California		2
Spain	(3)	33
Spanish		5
spit	(1)	1
strait	(4)	22
straits		2
stretch		1
thin		1
tongue		1
triangle		1
upper		2
Virginia		1
war	(1)	1
water	(6)	55
work		1
York		1
Yucatan	(1)	8

51. BINOMIAL.

Individuality Frequency, 63.

Failure Frequency, 6.

accuracy	(1)	1
algebra	(7)	118
algebraic		1
angle		1
annual		1
arithmetic		14
bilateral		1
bimanual		1
binocular		1
biometric		1
biometrical		1
bionomics		1
book		1
botany		1
calculus		1
classification		1
coefficient		1
college		1
comic sections		1
cousin		1
curve		3
decimal		1
diurnal		1
double	(2)	9
double name		1
dual		2
equation	(1)	13
expansion		3
exponent		2
factor		1
factors		1
figure		4
figures		1
formula	(1)	3
fraction	(1)	18
fractions		2
genetics		1
geometry	(1)	10
G.	(1)	1
glasses		1
grammar		2
Greek		1
G.		1
half		1
hyphen	(1)	1
letters		1
Linnaeus	(3)	6
logarithm	(1)	1
mathematical		1
mathematics	(6)	40
memory		1
monomial	(1)	6
multinomial		1
name	(4)	11
Newton	(2)	6
noim		1
nomenclature	(3)	12
noun		1
number	(1)	12
numbers		5
numeral		1
one		1
P.		1
physics		1
physiology		1
polynomial	(2)	10
power	(1)	1
problem		1
progression		1
pseudonym		1
quadratic		1
quantity		1
school		1
science		1
sentence		1
single		1
study		1
S.		2
surd		1
synonymous		1
system		3
term	(1)	1
terms	(1)	2
theorum	(54)	510
theory		28
trinomial	(2)	20
twice		3
two	(2)	48
two names		2
two number		1
two numbers		1
two parts		1
two term		1
unit		1
word		2
zoology		1

52. CRUSTACEAN.

Individuality Frequency, 93.

Failure Frequency, 7.

age		7
amphibian		2
amphibious		1
amphipod		1
anatomy		1
animal	(6)	69
animals		1
annelid		1
anthropology		1
antique		1
appendage	(1)	1
apple		1
arthropod	(1)	7
arthropods		1
astacus		1
baked		1
barnacle		2
biological		1
biology	(1)	30
bone		3
break		1
bugs		1
calcium		1
cambarus		1
carapace		1
cephalopod		1
cerulean		1
chrysanthemum		1
clam	(1)	6
clams	(1)	3
class		2
classification		2
coagulation		1
coating over		1
copapod		1
coral		3
covering		3
crab	(22)	139
crabs	(2)	5
crank		1
crater		2
crawfish	(2)	10
crayfish	(5)	37
crossing		1
crushing		1
crust	(1)	28
crustacea		1
crusty		2
crystal		4
crystallization		3
crystallography		1
crystallize		1
crystals		1
development	(1)	1
D.		1
dinosaur	(1)	1
early		1
earth		47
edge		1
encrusted		2
entomostracan		1
exoskeleton		1
fat		1
fish	(1)	26
flower		2
fluid		1
fossil		1
Friday Harbor		1
frog		1
frustration	(1)	1
geography		3
geological		1
geology		66
hard	(3)	16
hardening		4
hardness		1
horseshoe crab		1
incrustation		1
insect	(1)	7
insects		1
invertebrate	(1)	6
isopod		2
K.		1
laboratory		1
land		2
lava		1
legs		1
life	(1)	5
liquid		1
lobster	(15)	88
lobsters	(2)	4
lower animals	(1)	1
low life		1
mineralogy		1
mollusc	(8)	42
molluscan		1
molluscs		1
moon		1
moult		1
mud		1
ocean		1
organism		2
origins	(1)	1
oyster		10
oysters		1
paleontology		1
parasite		1
period		8
physics		1
physiology		1
pie		1
plant		4
pollen		1
primitive		2
pristine		1
protozoon		1
rain		1
rock		4
rocks		6
roughness		1
rough surface		1
salt		1
scale		1
school		2
science	(1)	5
scum		1
sea		5
sea shore		1
seek		1
shell	(8)	76
shelled		2
shell fish	(4)	20
shells	(2)	8
shelly		1
ship		1
shrimp		1
snail		2
snails		1
solution		1
star fish		2
study		1
surface		7
swamp		1
temper		1
thick		1
thickening		1
turtle		4
vertebrate		3
water		2
white		1
worm		1
zoology	(5)	37

53. BONAPARTE.

Individuality Frequency, 61.

Failure Frequency, 0.

Alps		1
ambition		2
Antoinette		1
army		1
battle		6
Beauharnais		1
Blenkins		1
bona fide		1
bone		1
Boney		1
Bordentown		1
Buonarotti		1
cartoon		1
Channing		1
commander		1
C.		1
Cornwallis		1
Corsica		9
Corsican	(1)	3
D.	(1)	1
Elba	(1)	4
emperor	(1)	2
England		1
Europe		1
explorer		1
fate		1
father		1
fool		1
France	(9)	101
French	(4)	20
Frenchman		1
French Revolution		2
gambler		1
general	(8)	61
genius		4
gorgeous		1
great		2
guinea pig		1
H.		1
hat		1
Helena	(1)	3
hero		2
history	(2)	16
horse		2
Iowa		1
island		1
joke		1
Josephine		7
king		1
leader	(1)	1
little	(1)	2
Louis		1
Louise		1
man	(2)	10
Maryland		1
Moscow		1
name		1
Napoleon	(45)	559
N.		1
niche		1
painting		1
Paris	(2)	3
picture		3
portrait		1
rascal		1
revolution	(1)	2
revolutionary		1
Rhine		2
ruler		1
Saint Helena	(3)	13
short		1
Sicily		1
smallness		1
soldier		5
Spanish		1
story		1
strength		1
successful		1
tomb		1
tyranny		1
tyrant		1
victor		1
Victor Hugo	(1)	1
victory		2
W.		1
war	(3)	12
wars	(1)	1
Washington		1
Waterloo	(9)	66
Wellington	(3)	14
W.		1

54. MERIDIAN.

Individuality Frequency, 83.

Failure Frequency, 1.

across		1
after		1
afternoon		1
altitude		1
angle		1
arc		1
artificial	(1)	1
astronomy	(5)	21
axis		1
azimuth		1
Boston		1
center		3
central		1
chart		1
China		1
circle	(1)	24
circles		1
cold		1
compass	(1)	2
Connecticut		2
day		2
derivation		1
diagram		1
dial		1
diatom		1
dies		1
distance		2
division		2
divisional		1
earth	(6)	50
East Boston		1
elliptic	(1)	1
England		1
equator	(3)	55
equinox	(1)	1
first		2
forty-ninth		1
Galileo		1
geodesy		1
geography	(9)	128
geology		1
globe	(2)	26
Greenwich	(9)	61
heat		4
heavens		3
height		2
hemisphere	(2)	5
high		2
hill	(1)	1
hops		1
horizon		1
horizontal	(1)	1
hot		2
hundredth		2
imaginary		4
imagination		1
Indianapolis		2
Iowa		1
isogenism		1
isothermal		1
land		1
latitude	(4)	39
line	(8)	146
lines		4

lodge		1
London		2
longitude	(9)	88
longitudinal		2
magnet	(1)	1
magnetic		1
map	(1)	26
measure		2
measurement	(1)	2
medium		1
Meredith		1
Meriden		2
meridian		1
Mercator		1
merit		1
midday	(1)	3
middle		7
midway		1
Mississippi	(2)	6
navigation		2
noon	(1)	24
north		3
North Pole		1
observation	(1)	1
observatory		1
one hundred eightieth		1
parallel	(7)	52
parallels		1
Paris		1
park	(1)	1
perpendicular		1
physical geography		1
physiography		2
physiology		1
place		1
point		1
pole	(1)	1
post		1
prime	(1)	7
sailing		1
Samoa		1
sea		1
seventy	(1)	1
seventy-fifth		1
sextant		1
shadow		1
sister		1
sky	(2)	7
south	(1)	3
South America		2
southern		1
space		1
sphere		4
standard		2
star		3
state		1
strait		2
straits		1
street		1
sun	(3)	23
surface		1
surveying	(1)	2
temperature		1
third		1
thirty-one degrees		1
time	(2)	21
transit		2
tropic		2
tropics		1
universe		1
voyage		1
Washington		3
watch		1
world		6
zenith	(2)	9
zero		1

55. CHLOROPHYLL.

Individuality Frequency, 59.

Failure Frequency, 33.

acid	(1)	2
aesthetic		1
alcohol		3
algae	(1)	3
algebra		1
amoeba		1
anaesthesia		1
anaesthetic		2
antiseptic		1
apothecary		1
biology		12
blankness		1
bodies		3
body	(1)	7
botanical		1
botany	(3)	42
cell		1
cells		1
cellulose		1
chemical		7
chemicals		1
chemistry	(2)	40
chloral		1
chloride		1
chlorine		2
chloroblast		3
chloroblasts		1
chloroform	(5)	121
chlorogue		1
chlorosis		1
color	(3)	58
coloring		12
composition	(1)	1
disinfectant		1
disinfected		1
doctor		2
drug		4
ether		2
fiber		1
flower	(4)	42
flowers		7
fluorescence		1
food		1
function		1
gas		3
grain		1
grains		1
granule	(1)	3
granules		4
grass		4
green	(36)	261
green grass		1
green leaves		2
greenness		2
habit		1
haemoglobin	(1)	2
hospital		1
interesting		1
juice		1
laboratory		1
leaf	(11)	61
leaves	(7)	26
life		1
light	(1)	2
lily		1
liniment		1
liquid		2
L.		1
magnesium		1
medicine		13
microscope		1
milky		1
name		1
odor		2
part		1
photosynthesis	(1)	2
physician		1
physics		1
physiology		2
pigment	(1)	2
plant	(12)	76
plants	(5)	36
Poe		1
poison		1
pollen		1
protoplasm		2
refraction		1
science		3
scientific		1
shell		1
sleep		3
smell		1
solution		2
spongy		1
stain		1
stamen		1
starch		6
structure		1
substance		1
sun	(1)	2
sunlight	(1)	6
teacher		1
term		1
tree		1
trees		1
tube		1
W.	(1)	3
Xanthophyl		1

56. TETRAHEDRON.

Individuality Frequency, 74.

Failure Frequency, 22.

algebra		2
angle		8
angles		2
animal		3
archaeology		1
arithmetic		3
arithmetical		1
article		1
astronomy		1
B.		1
beechnut		1
biology		1
blackboard		1
block	(2)	11
body		3
box	(2)	4
carbohydrate	(1)	2
carbohydrates		1
carbon	(3)	8
chemistry	(2)	5
circle	(1)	1
classroom		1
complexity		1
cone		1
coordinate		2
crystal	(9)	28
crystallography	(3)	8
crystals	(3)	6
cube	(1)	8
cylinder		1
decagon		1
decahedron		2
diagram		4
diamond	(1)	1
dodecahedron	(1)	3
drawing		2
edge		1
eight	(1)	4
evening		1
figure	(5)	106
fine		2
five		4
flower		1
force		1
form	(5)	25
four	(7)	55
four-side		1
four-sided	(1)	7
geography		1
geology		2
geometric		5
geometrical	(1)	6
geometrical figure		3
geometric figure		1
geometry	(14)	249
Greek		3
G.	(1)	1
group	(1)	1
head		1
heat		1
hectahedron		1
helio		1
hexagon		7
hexahedron	(1)	4
hexameter		1
hydra		1
hydrometer		1
hypothesis		1
icosahedron	(1)	7
instrument		1
irregular		2
isomerism	(1)	2
isosceles	(1)	8
jelley fish		1
L.		1
M.		1
many		1
many sided		1
mathematics	(1)	32
measure		1
metric		1
mineralogy		3
model		2
nucleus		1
object		3
octagon		2
octahedron	(1)	12
ox		1
oxyhedron		1
parallelogram		2
parallelopiped		2
pasteboard		2
pentagon	(1)	2
pentagonal	(1)	1
pentahedron		1
plane		1
plant		1
polygon	(1)	21
polyhedron	(3)	15
prism		4
puzzle		1
pyramid	(2)	11
quadrahedron		2
quadrilaetral		1
quadruped		1
rectangle	(1)	2
red		1
rhombohedron		1
rhomboid		3
rock		1
Sanhedrin		1
school		1
science		2
seven		2
sextrahedron		1
shape	(4)	18
sides	(1)	4
singer		1
six	(1)	3
six-sided		1
size		2
solid	(6)	53
solid geometry		6
solids		1
space		1
square	(2)	14
stereochemistry		2
structure		2
sulphur		1
surface		2
technology		1
ten		1
tetahexahedron		1
tetanus		2
tetragonal		1
tetrahedral		1
tetrameter		2
tetrapod		1
Tetrazzini		5
text book	(1)	2
three		9
titron		1
tobacco		1
triangle	(3)	25
trigonometry	(1)	12
trihedral		1
virtues		1
volume		2
water		1
worm		1

57. MADAGASCAR.

Individuality Frequency, 101.

Failure Frequency, 1.

Africa	(18)	143
Alaska		1
alligator		1
America		1
ape		1
Asia		1
Australia		4
automobile		1
awk		1
aye-aye		1
Balboa		1
bay		18
Bernadotte		1
black		1
blacks		1
Borneo		2
Britain		1
British		1
cannibal		1
cannibals		1
cape		8
Ceylon		1
channel		1
charades		1
Chili		1
city		5
cloth		1
coast		1
colonization		1
colony		1
colored		2
continent		1
country	(4)	26
Cuba		1
dark		1
discoverer		1
dodo	(1)	1
dummy		1
eastern		1
England	(1)	2
English		1
entomology		1
Europe		1
exploration		2
explorer		2
flora		1
foreign		2
F.	(1)	1
France	(2)	15
Freiligrath		1
French	(3)	17
geography	(5)	61
Gibraltar		1
globe		1
grapes		1
Greenland		1
heathen		2
Helgoland	(1)	1
history		2
Hova	(1)	1
India		1
island	(44)	361
ivory		1
Jaffa		1
Japan		1
Jerusalem		3
king	(1)	1
Labrador		1
land		10
lascar		2
lemur	(1)	1
lemurs		1
madrigal		1
Magellan		5
maid		1
Maine		1
Malay		3
man		1
Mandalay		1
map	(2)	15
matting		1
Mauritius		2
metaphysics		1
mission		1
missionary		2
moa		1
monkey		2
Moor		1
Morocco		1
Mozambique	(2)	2
Napoleon		1
nation		1
native		3
natives		1
negro		9
negroes		2
niggers		1
ocean		1
oranges		1
orient		2
peninsula	(1)	10
people		1
picture		1
place		5
Portugal		2
province		1
queen		1
races		1
Ravalona	(1)	1
region		1
remote		1
round island		1
savages		2
Saint Pierre		1
scramble	(1)	1
sea		4
Senegambia		1
Slocum		1
south		2
South Africa	(1)	2
South America		4
southern		1
Spain	(1)	21
spices		1
sporotrichosis		1
state		2
strait	(3)	59
straits	(2)	37
sword		1
Tamerlane		1
Tananarivo		1
Tasmania		1
Tierra del Fuego		1
town		1
travel	(1)	2
troiss gudheen		1
tropics		1
Turkey		1
W.		1
W.		1
war		1
water		5
wine		2
woolly Indians		1
word	(1)	1
yellow		1
Zanzibar	(1)	3
zoography		1
Zulu		1

58. COROLLA.

Individuality Frequency, 104.

Failure Frequency, (3) 75.

ambition		1
analogy		1
ancient history		1
animal		3
aster		1
astronomical		1
astronomy		6
aurora borealis	(1)	1
beauty		1
bee	(1)	1
biology		3
blossom		2
boat		1
body		2
bone	(1)	1
borealis		2
botanical	(1)	2
botany	(3)	54
calyx	(6)	41
carol		1
C.		1
cerebellum		1
cheese		1
chlorophyll		1
chorea		1
circle		5
cobra		1
collar	(1)	5
color		6
comma		1
copula		1
C.		1
coral	(1)	37
corals		6
Corelli		1
cornea		1
corollary	(1)	37
corona	(4)	21
coronen		1
corral		2
correlate		1
correlative		2
correspond		1
covering		1
crown	(2)	21
crowned		1
cruller	(1)	2
crullers		1
cup-shaped		1
curve		1
daisy		2
derivation		1
diagram		1
disease		1
dogwood		1
enclosure		1
envelope		1
Esse		1
eye		8
fish		1
flower	(34)	330
flowers	(1)	13
following		1
fringe	(1)	1
gem		1
geological		1
geometry		9
gorilla		1
grammar		1
guerilla		1
halo		1
head		1
hypothesis		1
infer		1
insect	(1)	2
island		3
Koran	(1)	1
Latin		1
light		3
lily		3
logic		1
L.		1
L.		1
marble		1
M.		1
mathematics		2
Mexican		1
moon	(1)	4
morning glory		2
morphology	(1)	1
moth		1
Naples		1
narcissus		1
neck		3
nerve	(1)	1
Newton	(1)	1
ocean	(1)	1
painter		1
painting		1
pansy		1
part		1
penumbra		1
perianth	(2)	4
petal	(6)	26
petals		17
petiole		1
physiology		1
pink		1
pistil	(1)	10
pistils		1
plant	(8)	47
plantago		1
plants	(1)	5
pollen	(2)	8
Porto Rico		1
principle		1
pronounciation	(1)	1
queer		1
red	(1)	2
reef		1
resulting		1
ring		3
rocks		1
R.		1
science		1
sea		2
seed	(1)	1
sepal	(1)	3
sepals		1
shape		1
similar		1
snake		2
Sorella		1
sound		1
Spain		2
Spanish		1
spermifites	(1)	1
spiked		1
stamen	(1)	7
stamens	(1)	6
star		4
stem		1
stone		1
sun	(4)	25
supplement		1
teacher		1
technical		1
theorum		3
together		1
tooth-paste		1
triangle		1
truth		1
white		2
word		1
yellow		1
zoology		1

59. VENTRAL.

Individuality Frequency, 102.

Failure Frequency, (3) 15.

abdomen	(1)	8
abdominal		5
aboral		1
above		1
alimentary		1
anatomy	(1)	12
animal	(1)	9
anterior	(1)	4
aorta		1
apex		1
artery		1
aspect	(1)	2
atrocities		1
aural		1
auricle	(1)	11
back	(2)	21
being		1
belly	(7)	21
below	(1)	6
beneath		1
B.		1
biology	(1)	7
blood		3
body	(2)	18
botany		1
bottom		2
bowel		1
brain		8
bursting		1
canal		2
cavity	(1)	5
cell		1
centre		1
central	(1)	2
column		1
come		1
cord	(1)	1
crayfish		1
cut		1
deep		1
diaphragm		1
dictionary		1
digestion		1
door		3
dorsal	(34)	201
down	(1)	2
ear		1
earthworm		1
electrocardiogram		1
entrance		2
exit		3
eye		1
face		1
facial		1
fan		1
fin		5
fish		3
fixation		1
flat		1
floor		1
forward		1
frog		3
front	(3)	35
fur		1
gap		1
gastropods	(1)	1
hadrome		1
half		1
heart	(5)	124
hernia		4
hole		1
hollow		1
human		1
hydroxygen		1
internal		1
intestinal		1
intestines		2
island		1
lateral		4
leaf	(1)	1
leaves		2
left		11
lobe		1
lobular		1
low		1
lower	(3)	16
lungs		2
Marchantia		1
median		2
medical		1
morphology		1
mouth		1
nerve		3
nervous		1
nose		1
occipital		1
open		1
opening	(1)	28
oral		1
organ		4
orifice	(1)	2
outlet		1
outside		1
pericardium		1
peripheral	(1)	1
peritoneum		1
physical		1
physiology		30
picture	(1)	1
pin		1
position		4
posterior		6
process		1
psychology		1
rear		1
region		1
right		6
right		6
segment	(1)	7
segmentation		1
segments		1
side	(4)	29
sides		2
sinistral	(1)	1
space		1
spinal		2
spine	(1)	1
sternal		1
stomach	(8)	66
superior		1
surface	(1)	9
surgery		1
suspension		2
system		3
teacher		1
throat		2
top		1
towards me		1
tribobate		1
tube		1
tubercular		1
under	(1)	21
underneath	(1)	4
under side		1
upper		1
valve	(2)	6
vein		6
veins		1
Venezuela		1
vent		3
ventil		1
ventilate		1
ventilation	(1)	2
ventnor		1
ventres		1
ventricle	(1)	10
ventriloquism		4
ventriloquist	(1)	20
ventrimeter		1
ventrix		1
vertebrate		1
vitriol		1
voice		2
vortex		1
west		1
wind		23
window		3
zoological		1
zoology		4

60. BELGIUM.

Individuality Frequency, 84.

Failure Frequency, 1.

accident		1
Albert	(2)	10
allies	(1)	1
anguish		1
Antwerp		7
army	(1)	1
atrocities		5
atrocity		4
Austria		1
bank		1
battle	(1)	3
battles		1
Belgae		1
Belgian		3
bellicose		1
black		1
brave		2
bravery		3
bravest		1
Brussels	(10)	33
Caesar		1
calamity		1
canals		1
Cerfontaine		1
Chamisso	(1)	1
city	(1)	1
Congo		3
contribution		1
cooperation		1
country	(9)	92
crime		1
cruelty		1
destroyed		1
destruction		4
devastation		1
disaster		1
dog	(1)	1
Dutch		2
England		3
Europe	(5)	51
European		1
famine		1
Flanders		1
foreign		1
France	(1)	29
Francois		1
French		2
Gaul		1
Gembloux		1
geography	(2)	10
German	(1)	6
Germans	(1)	7
Germany	(3)	53
glass		1
government		2
hare	(1)	6
hares		1
hell		2
history		1
Holland	(16)	100
homeless		1
horror	(2)	5
horrors	(1)	3
hunger		1
hungry		1
invasion		1
island		2
Italy		1
Kaiser		5
king		5
King Albert		2
knitting	(1)	3
lace		1
land	(2)	7
lavender		1
Leopold	(2)	20
Liege	(1)	8
location	(1)	1
Louvain		9
low	(1)	1
Maeterlinck		1
map	(1)	13
massacre		1
minds		1
misery		2
misfortune		1
Mons		1
murder		1
Napoleon		1
nation		4
Netherlands		5
neutral		2
neutrality		7
oppression		2
outrage	(1)	1
painting		1
peace		1
people		5
pillage		1
plain		1
politics		1
poor		3
Portugal		1
present war		1
Prussian	(1)	1
queen		1
refugee	(1)	6
refugees	(1)	1
relief		13
rubber		1
small		1
smallness		1
smashed		1
socks		1
soldier		5
soldiers		2
Spain		12
starvation		1
state	(2)	9
strike		2
suffer		1
sufferers		2
suffering	(1)	15
sufferings		1
Swede		1
Switzerland		1
tragedy		1
treaty		2
troops		1
trouble		2
Turkey		1
uniforms	(1)	1
university	(1)	1
valor		1
violation		1
Wales		1
war	(20)	286
warfare		1
Waterloo	(1)	5
W.	(1)	1
Wilhelm		1
woe		1

61. TANGENT.

Individuality Frequency, 74.

Failure Frequency, 0.

across		1
adjacent		2
adjoining		1
aeroplane		1
against		1
anger		2
angle	(3)	17
angles		1
arc	(1)	1
at		1
away		2
bicycle		1
branching		1
chord		1
circle	(22)	249
circles		1
circumference	(1)	4
close		2
comet		1
contact		1
cosecant	(2)	14
cosine	(3)	9
cotangent	(10)	84
curve	(3)	16
derivative		1
deviation		2
diagram	(1)	2
different		2
differential		1
divergence		1
drawing		1
drunk		1
Emma		1
even		1
falling		1
figure		4
figures		1
flag		1
flying		4
flying off		1
force		1
function	(1)	2
galvanometer		2
geometrical		1
geometry	(6)	107
G.		1
going		1
going off		1
go off on	(1)	1
hanging		1
Heidelberg		1
hypothenuse		1
idiosyncracy		1
joining		1
junction		1
life		1
line	(9)	110
lines		1
mathematics	(3)	21
mistake		1
movement		1
near		1
nearness		1
next		1
oblique		2
of a circle		1
off		6
offshoot		2
opposite		1
physics		2
picture		1
plain		1
procession		1
projection		1
queer	(1)	1
radial	(2)	2
radiating		1
radius		5
railroad		1
railroads		1
ratio	(1)	1
rays	(1)	1
relation	(1)	1
right angle		1
secant	(11)	81
section		2
show		1
side		7
sine	(5)	22
slant		3
sling		1
sphere		2
steel		1
stick		1
straight		5
stretching	(1)	1
surveying		1
tangential		4
tangerine		1
tango		2
tantrum		2
T.		1
temper		2
tetrahedron		1
text-book		1
time		1
to		1
touch	(1)	12
touching	(1)	20
tracing		1
triangle	(1)	8
trigonometry	(8)	76
unite		1
vicinity		1
V.		1
wheel		2
wild		1

62. DORSAL.

Individuality Frequency, 62.

Failure Frequency, (1) 10.

abdominal		1
above	(1)	5
anatomy	(2)	11
animal	(1)	4
anterior		3
architect		1
aspect	(1)	4
back	(24)	270
backbone	(2)	7
behind		1
below		1
biology	(1)	6
body		6
bone		9
bones		1
botany		1
brain		2
breathing		1
canal		1
cavity		4
charts		1
column	(1)	3
cord	(1)	1
curve		1
direction		1
docile		3
door		2
door-sill	(1)	2
door-step		1
D.		2
D.		1
D.		1
entrance		1
fin	(8)	103
fins		3
fish		21
flesh		1
foot		1
frog		2
front		6
frontal		2
geology		1
grasshopper		2
head		2
heart	(1)	6
horseback	(1)	1
jamb		1
leaf	(1)	1
left		2
lower		1
lumbar		1
lung		1
lungs		1
man		1
manikin	(1)	1
medicine		1
meek		1
membrane		2
metatarsal		1
mind		1
motion		1
muscle		3
nerve	(1)	3
nerves		1
nose		1
opening		1
opposite	(1)	1
paleontology		1
part		1
peace		1
physical		2
physiological		1
physiology		19
position	(1)	4
posterior	(1)	7
psychology		2
quiet		4
radial		1
rear		3
right		2
science		2
section		1
shark	(1)	5
sharks	(1)	1
side	(3)	17
skull		1
sleep		1
slit		1
snake		1
soft		1
spinal		5
spinal cord		1
spine		12
spiny		1
stomach		1
straight		1
surface	(1)	3
tail		1
teacher		1
thin		1
top		7
under		3
up	(1)	1
upper	(3)	21
upper side		1
valve	(1)	1
vein		3
ventral	(34)	243
vertebra	(1)	17
vertebrae	(2)	29
vertebrate		9
vertebrates		1
waist		1
whale		6
worm		1
zoology		3

63. COLLOID.

Individuality Frequency, 168.

Failure Frequency, (1) 141.

advertisement		1
albumen	(3)	9
albuminoid	(1)	1
albuminous		1
alcohol		2
alloid		2
alloy		1
aluminum hydrate		1
amoeba	(1)	1
amorphous	(1)	2
analysis		1
anatomy		4
arrow		1
artery		1
asteroid		1
balloon		1
biology	(1)	8
blood	(1)	2
body		4
bone		12
bones		1
botany		1
c.		1
calor		1
calyx		1
carbohydrate		1
carload		1
casein	(1)	1
cell	(1)	8
celloidin		1
celluline	(1)	1
celluloid		66
cellulose		1
cement		1
chemical		13
chemistry	(12)	132
chloral		1
chlorophyll		1
chocolate		1
cholera		1
chromogen		1
circle		1
circus		1
class		1
clouded		1
coagulate		2
coagulation		2
coal oil		1
coat		1

Coliseum		1
collar		29
collar bone		1
collate		1
collateral		1
colleague		1
collection		1
college		2
collide		4
collision		1
collodic		1
collodion		4
collodium	(1)	7
colloidal		2
collop		1
collusion		1
colon		1
color	(1)	8
columbine		1
column		8
columnar		1
combination		1
compound		3
condition		2
conjunction		1
cool		1
copper		1
coral		1
covering		1
crown		1
crystal	(2)	5
crystalline	(1)	3
crystallization		1
crystallize		1
crystalloid	(10)	38
cylinder		1
dense		1
derivation		1
derivative		1
dialysis		1
dictionary		1
dietetics		1
diffusion	(1)	1
drug		2
drugs		1
dynamite		1
egg		5
egg-white		1
electrolyte		1
enzyme		1
ether		1
eye		1
fat		2
ferric hydroxide		1
film		1
filter		1
F.		1
fluid	(1)	1
food		1
form		3
gel		2
gelatin	(3)	8
gelatinous		5
geology		1
geometry		2
glue	(3)	11
glue-like		1
gluey	(1)	1
goitre		1
gold	(1)	8
G.	(1)	3
Greek		1
green	(1)	1
gum	(1)	2
hand		1
hanging		1
hard		2
haziness		1
heat		3
human body		1
immunity		1
impenetrable	(1)	1
insoluble		3
iron		2
isinglass		1
isocolloid		1
jelly	(9)	28
jelly-like		1
joke		1
K.		1
Kipling		1
L.		1
large		1
lipoid		1
lipoids		1
liquid		5
L.		1
L.	(1)	1
mass		2
mastoid		1
material		3
matter		1
medical		2
medicine		5
member		1
membrane	(1)	8
metal		2
milk	(1)	2
mineral		1
mixture	(1)	6
molasses		1
molecule		2
motion	(1)	1
mucilage		1
mucoid		1
mucus		1
muscle		1
neck		5
nerve	(1)	1
non-diffusible		1
nothing		2
oil		1
osmosis	(2)	4
O.		6
palladium		1
parchment		1
particle	(1)	3
particles	(1)	1
pasty	(1)	1
pen		1
penetrable		1
physics		2
physiology		10
pigment		1
plant		2
plate		1
precipitate		6
precipitation		2
preparation		1
process		3
proteid		3
protein	(1)	3
protoplasm	(3)	9
purification		1
rhomboid		1
science		5
scientific		1
scollop		1
semi-permeable membrane		1
sewage		6
shape		1
shapeless		1
silica		2
silver		1
skin		1
sky		1
small	(1)	2
smoke		1
society		1
soft		2
soil		1
sol		1
solid		3
solution	(9)	34
spelling		1
spheroid		1
spiral		1
starch	(1)	7
state	(1)	1
sticky		5
stiff		1
stiffness		1
structure		1
study		1
substance	(3)	22
sugar		1
surface tension	(1)	1
suspension		6
suspensions	(1)	1
system	(1)	1
tabloid		1
talcum		1
tar		1
teacher		1
telelology	(1)	1
term		1
thick	(1)	11
throat		1
thyroid	(1)	4
thyroid gland		1
tissue		4
together		2
translucent		1
tumor		1
turbidity	(1)	1
turning		1
uncrystalline		1
unfilterable		1
unmixable		1
viscous	(1)	2
water		1
weed		1
wood		1
word		1
zoology		3

64. EQUATOR.

Individuality Frequency, 77.

Failure Frequency, 0.

Africa	(1)	4
Amazon		3
Ancient Mariner		1
antipodes		1
apple		1
astronomy		1
axis	(1)	1
band		1
basal		1
belt	(1)	6
black	(1)	1
Borneo		1
Brazil	(1)	10
cacti		1
camel		1
Capricorn		4
Carribbean		2
center	(2)	24
central	(1)	8
ceremony		1
Chili		2
circle	(9)	32
circular		1
circumference	(1)	2
Clemens		1
climate		1
cold	(1)	1
crossing		3
Cuba		2
curve		2
declination	(1)	1
depression	(1)	1
diameter		3
distance		2
divides		1
dividing		2
doldrums		2
ducking		1
earth	(15)	160
Ecuador	(2)	7
Egypt		1
encircle		1
equal		6
equalizing	(1)	1
equation		1
equator		1
equinox	(1)	5
friend		1
geographical		1
geography	(5)	55
girdle		1
globe	(4)	26
goal		1
hair		1
half		2
heat	(1)	52
hemisphere	(1)	4
horizontal		1
hot	(8)	65
imaginary		6
imaginary line	(1)	2
imagination		1
island		1
isthmus		1
Java	(1)	1
jungle		1
Kipling		1
land		1
latitude		6
line	(11)	147
localities		1
longitude		1
luxuriant	(1)	1
Magellan		1
Malay		1
map		11
Mark Twain	(2)	4
mathematical	(1)	1
medium		1
Mercator		1
meridian	(8)	64
Mexico		3
middle	(1)	17
middle line		1
midway		2
Neptune		1
north		1
North Pole		4
Panama		7
parallel	(1)	9
Peary		1
Peru		1
picture		1
place		2
pole	(4)	27
poles		5
position		1
Quito		2
quotation		1
race		1
Roosevelt		1
round		7
running		1
seed		1
side		1
south		14
South America		13
southern		1
sphere		1
spheroid		1
story		1
substantive		1
sun	(1)	14
Tahiti		1
temperate	(1)	1
torrid	(2)	12
torrid zone		1
tropic	(1)	9
tropical		1
tropics	(4)	18
Twain		1
vernal		1
vessel		1
voyage		1
warm		5
warmth		1
world	(1)	15
zodiac		1
zone		5
zones		1

65. JUDICIARY.

Individuality Frequency, 80.

Failure Frequency, 1.

act		1
action		1
administration	(1)	2
administrative		1
appointment		1
authority		1
awe		1
bad		1
balance		1
bench	(1)	17
beneficiary		2
body		9
boy		1
B.		1
B.		1
circuit		1
civics		4
civil		1
civil government		1
commission		1
committee	(1)	5
congress		1
conservative		1
constitution		1
contrast		1
court	(9)	142
courtroom	(1)	3
courts	(6)	35
crime	(1)	2
C.		1
decision		1
decisions	(1)	3
department		7
dignity		2
election	(1)	1
English		1
equity		3
executive	(1)	23
false		1
federal	(2)	9
force		1
form		1
function	(2)	7
government	(5)	40
governor		1
graft		2
grave	(1)	1
G.		1
hair		1
history		1
H.		2
Japan		1
joke		1
Judas		1
judge	(25)	271
judges	(3)	41
judging		3
judgment	(2)	11
judicate		1
judicial	(1)	5
judicious	(1)	2
jury	(1)	2
just		1
justice	(2)	26
law	(8)	129
laws	(1)	4
lawyer		4
lawyers		1
legal	(3)	13
lega lsystem		1
legislation		1
legislative	(3)	15
legislature	(1)	8
level		1
L.		1
L.		1
lynch	(1)	1
magistrate		2
man		1
management		1
M.		3
Massachusetts		1
Mc.		1
men		1
midnight		1
military		1
municipal		1
Napoleon		1
national		2
nominations		1
nominators	(1)	1
office	(1)	3
peace		1
P.		1
police	(1)	1
politics		3
power		2
powers		3
proceedings		1
progressive		1
punishment		1
recall	(2)	8
referendum		2
reform	(1)	4
right		1
rightness		1
robe		1
Roosevelt	(1)	6
senate		1
settlement	(1)	1
state		1
supreme	(1)	6
supreme court	(3)	6
systems		1
T.	(1)	7
terminology		1
T.		1
thief		1
think		1
trial	(2)	3
trials		1
tribunal		2
unbiased		1
usurpation		1
voting		1
war		1
Washington		2
W.		2
W.		1
wig		1
wigs		1
wise		1

66. SYNTHESIS.

Individuality Frequency, 123.

Failure Frequency, 14.

action		1
addition	(2)	4
adverb		1
agreement		1
alcohol		1
algebra		3
alike		1
anabolism		1
analogy		1
analysis	(38)	308
analytics		1
analyze	(1)	2
analine		1
anthesis		2
antithesis		28
argument		2
arrangement		2
assemble		2
assembling		2
association		1
ball		1
Bible		1
biology		2
blending		1
bone		1
bones		1
botany		2
break		1
breaking		1
build		9
building	(2)	20
building up		4
carbohydrates		1
carbons		1
catabolism		1
cell		1
chemical	(3)	6
chemical operation	(1)	1
chemicals		2
chemist		1
chemistry	(12)	57
chemotherapy		1
chlorophyll		1
coal tar		1
coherence		2
cohesion		3
collection		4
combination	(5)	30
combine		1
combining	(1)	6
comparison		2
complex	(1)	2
compose		1
composition	(1)	4
compound		5
compounding		1
compounds	(1)	1
conclusion		1
connection		2
connections		1
construct		1
construction	(1)	12
contact		1
coordination		1
creature		1
C.		1
decomposition		2
development		1
dialysis	(1)	3
diathesis	(1)	3
dictionary		2
digestion		1
disintegration		1
division		5
dovetailing		1
elaboration		1
elements	(1)	1
English		4
ether		1
ethylene		1
examination		1
F.		1
food		1
foot	(1)	1
form		1
formation	(1)	5
fusion	(1)	1
gathering		3
gems	(1)	1
glycocoll		1
grammar	(1)	44
Greek		2
group		1
grouping		2
harmony		2
heat		1
hoe		1
hypothesis		1
integration		1
intellectual		1
join		1
joining		6
Kant		1
katabolism		1
laboratory	(1)	1
language		1
Latin		1
life		1
light		4
likeness		5
line		1
literature		2
logic		12
make		5
making	(1)	4
manufacture		3
material		1
mathematics		1
M.		1
medicine		1
metabolism	(1)	5
metathesis		1
method		5
mind		1
mixing		1
molasses		1
Oneness		1
opposite		2
opposition		2
organic		7
organic chemistry		1
organization		2
outline		1
parenthesis		1
part		1
philosophy		4
photo		2
photosynthesis	(1)	9
physics		1
picture		1
plant	(1)	2
plants		1
preparation		2
process	(1)	5
production		1
proteins		3
psychology		4
psychosis		1
pubes		2
put		1
putting		3
putting together	(1)	14
put together		3
reaction	(1)	5
reasoning		1
reconstruction		1
relate		1
relation		1
result		1
rhetoric	(1)	3
rubber		2
rule		1
sacrum		1
same		1
science		4
sentence		9
separate		2
separation		4
similarity		1
skull		1
snarl		1
spelling		1
Spencer		1
starch	(1)	1
substance	(1)	1
substances		1
substitution		1
sun		1
symmetry		2
sympathy		1
synchronistic		1
syncopate		1
synopsis		1
syntax	(2)	24
synthetic		8
system		1
tearing		1
text-book		1
thesis		1
think		1
thought		1
titration		1
together	(7)	55
union	(2)	13
unite		1
uniting		1
upward		1
urea		2
vanilla		1
vital		1
W.		1
water		3
whole		4
words		1
Wurz method		1

67. ATHENS.

Individuality Frequency, 56.

Failure Frequency, 0.

acropolis	**(1) 22**	**classic**	**1**	**Greece**	**(72) 651**	**pacific**	**(1) 1**	**Solon**	**(1) 1**
ancient	**2**	**classical**	**2**	**Greek**	**23**	**palace**	**1**	**south**	**1**
ancient city	**1**	**columns**	**1**	**Greeks**	**3**	**Parthenon**	**(1) 21**	**Spain**	**1**
architecture	**2**	**country**	**2**	**Herodotus**	**1**	**Paul**	**6**	**Sparta**	**(3) 25**
Areopagus	**1**	**culture**	**(1) 10**	**hill**	**3**	**peninsula**	**2**	**state**	**2**
Aristotle	**1**	**Diana**	**1**	**historical**	**1**	**Pericles**	**(1) 13**	**statuary**	**(1) 1**
art	**8**	**dirt**	**1**	**history**	**(1) 12**	**Phidias**	**1**	**statutes**	**1**
Athena	**1**	**Doric**	**1**	**Homer**	**1**	**place**	**2**	**study**	**1**
atoms	**1**	**Europe**	**2**	**Horns**	**1**	**Plato**	**1**	**symmetry**	**1**
beauty	**2**	**eye**	**1**	**Iowa**	**1**	**poetry**	**1**	**temple**	**3**
book	**1**	**fall**	**1**	**learning**	**1**	**Prophylaea**	**1**	**Texas**	**1**
building	**1**	**games**	**1**	**maid**	**1**	**Pyrrhus**	**2**	**town**	**3**
bust	**1**	**general**	**1**	**Mannott**	**1**	**R.**	**1**	**university**	**1**
Byron	**1**	**geography**	**(2) 3**	**Minerva**	**1**	**Rome**	**(3) 38**	**Venice**	**1**
candle	**1**	**Georgia**	**4**	**Naples**	**(1) 1**	**ruin**	**1**	**Venizelos**	**1**
capital	**3**	**glory**	**3**	**nation**	**1**	**ruins**	**3**	**war**	**(1) 1**
Carthage	**1**	**government**	**2**	**Ohio**	**4**	**Salamis**	**1**	**warrior**	**1**
city	**(6) 55**	**grandeur**	**1**	**owls**	**(1) 1**	**sculpture**	**5**	**white**	**1**
civilization	**(1) 1**								

68. EPITHELIUM.

Individuality Frequency, 110.

Failure Frequency, (2) 84.

above	1	chitin	(1) 1	episode	1	literature	1	protozoon	1
after	2	cilia	(1) 2	epithalamium	9	low	1	psychology	3
against	1	ciliated	1	epithallium	1	marriage	2	Pygmalion	1
amphitheater	1	columnar	3	epithelioma	1	mathematics	1	Rome	2
anatomy	4	connective tissue	(1) 1	epitherium	1	medicine	2	scales	(1) 1
ancient	4			epithet	(1) 8	membrane	(2) 5	science	4
animal	(1) 2	construction	1	epizootic	1	mesoderm	1	scutum	1
architecture	2	corium	2	E.	1	mesothelium	(1) 2	sheet	1
art	2	cover	(1) 3	erechtreum	1	metal	1	skin	(50) 431
Asia Minor	1	covering	(2) 12	eye	(1) 2	Milton	1	skull	1
astronomy	4	cuticle	1	fin	1	morphology	1	small-pox	1
Athens	(1) 3	cutis	1	finger nails	1	mortation	1	smell	1
bark	1	dermis	(1) 2	flesh	1	mouth	(1) 5	solar	1
battle	1	dictionary	1	flower	(1) 1	mucosa	(1) 1	Spencer	5
B.	1	down	1	fly	1	mucous	1	squamous	1
bed	1	duodenum	2	frog	(1) 1	negro	1	stomach	1
biological	1	ear	2	gland	1	nose	1	submucous	1
biology	(1) 7	earthworm	1	Greece	11	olfactory	1	substance	1
biozoological	1	ellipse	1	Greek	24	on	1	sun	2
blank	1	emporium	1	hair	1	outer	(2) 3	superficial	1
blood	1	endoderm	(1) 1	hall	1	outside	8	surface	12
body	8	endothelium	5	hallway	1	palate	1	teacher	1
bone	2	ephesis	1	hand	1	paracentral	(1) 1	temple	2
botany	5	epic	2	heat	1	pavement	1	theater	(1) 1
brain	5	epicanthus	1	histology	6	perihelion	1	Thebes	1
bronchial	1	epicurean	3	hymn	1	perimeter	1	theory	1
calyx	1	epidermis	(1) 17	interior	1	physiology	(1) 19	tissue	(5) 37
cancer	3	epidural	1	intestine	1	pithy	1	tongue	1
carcinoma	1	epigastrium	1	Latin	3	place	1	top	1
cell	(8) 34	epigram	1	layer	3	plant	1	trachae	1
cells	(7) 28	epigrammatic	1	leaf	2	poetry	2	trillium	1
cell-tissue	1	epilepsy	2	light	1	problem	1	upon	3
cellular	1	Epimetheus	1	lining	10	protection	(1) 2	W.	1
ceremony	1	epiphilial	1	lip	1	prothallium	1	zoology	3
chemistry	3								

69. FEUDALISM.

Individuality Frequency, 113.

Failure Frequency, 2.

abolish	**1**	**ancient**	**(1) 15**	**aristocracy**	**2**	**barbarism**	**10**	**capitalism**	**(1) 2**
absolutism	**1**	**ancient history**	**(1) 1**	**armament**	**(1) 1**	**barbarity**	**1**	**caste**	**1**
A.	**2**			**armor**	**7**	**baron**	**(8) 40**	**castle**	**(5) 39**
ages	**3**	**ancient laws**	**1**	**attempt**	**1**	**barons**	**(4) 25**	**castles**	**(1) 6**
agrarian	**1**	**antique**	**1**	**autocracy**	**1**	**beneficient**	**1**	**cavalier**	**1**
anarchism	**1**	**antiquity**	**1**	**barbarians**	**(1) 1**	**bloodshed**	**1**	**Central Europe**	**1**
anarchy	**2**	**arbitrary**	**(1) 1**	**barbaric**	**1**	**bosses**	**1**	**chains**	**1**

Charlemagne 2
C. 1
chivalry (5) 39
church 2
condition 3
country 1
Crecy 1
creed 1
Cromwell 1
crusade (1) 1
crusades 2
drak 3
drak ages (1) 1
democracy (2) 4
dependent 1
disturbance 1
dues 1
dukes 1
early 1
England (2) 51
English 3
Europe (2) 24
extinct 1
farmer 1
federalism 1
feud 1
feudal (1) 1
feuds 2
few 1
fief (2) 5
fight 3
fights 3
force 1
France 15
futile 1
Gaul 1
German 2
Germany (1) 16
government (3) 23
Guizot 1
gun 1
history (5) 70
homage 1
injustice 1
inquisition (1) 1
institution 1
Ireland 1
Ivanhoe 1
Japan (1) 4
John 1
Kaiser 1
Kentucky 1
king 2
King Arthur 2
King Richard I 1
kings 2
knight (4) 40
knighthood (1) 10
knights (4) 25
K. (1) 1
land 5
law (1) 7
light 1
lord (2) 29
lords (4) 27
love 1
man 1
manor 6
master 1
mediaeval (4) 78
mediaevalism 12
men 1
Mexico 1
middle ages (6) 46
military 1
moat 2
monarchism (1) 1
monarchy (1) 5
monastician (1) 3
monks 1
nation 1
nobility 1
noble (1) 2
Norman (1) 4
Normans 1
nuisance 1
old 1
old English history 1
oligarchy 1
oppression 4
pageantry 1
party (1) 1
past 1
patron 1
pauperism 1
peace 1
people 2
period 1
politeness 1
politics 1
poverty 1
power 3
rebellion 1
regime 1
religion 1
Renaissance 3
republicanism 1
Richard 1
rifle 1
right 1
romance 2
R. 1
Rome 1
royalty 1
rule 1
Russia 1
Scott 3
serf (3) 17
serfdom 2
serfs (2) 9
servitude (1) 1
slave 4
slavery (3) 20
slaves 3
social (1) 1
socialism 1
society 4
south 1
Spain 2
Sparta (1) 2
state 4
strife 7
stupidity 1
swords 1
system (1) 18
Tennessee 1
tenure 1
time 2
tournaments 1
tribe (1) 1
tyranny 2
tyrant 1
tyrants 1
vandal 1
Vandalism 3
vassal 4
vassalage 1
vassals 2
Venice 1
voting 1
walls 1
war (1) 27
wars 1
William the Conqueror (1) 1

70. COEFFICIENT.

Individuality Frequency, 114.

Failure Frequency, 11.

a. 1
absorption 1
accompanying 2
action 1
adhesion (1) 1
algebra (5) 147
algebraic 3
analysis (1) 1
angle (1) 3
annex 1
annual 1
arithmetic 25
before 4
binomial 6
binomial theorum 1
biometrics 1
brass 1
business administration 1
calculations (1) 1
calculus 2
coagulate 1
coequal 1
college 1
company 1
comparison 2
completion 1
conjunction 1
connection 1
cooperation 1
cooperative 1
corallin 1
corollary (1) 1
corporation 1
correlation (8) 44
correlative 2
cosine 2
cypher 1
decimal 1
deficient 1
degree 1
denominator 1
differential (2) 3
diffusion 1
digestibility 1
digestion (1) 2
digression 1
disinfectants 1
division 4
divisor 2
education 1
efficiency 4
efficient (2) 13
elasticity 2
energy 3
English 1
equal 14
equality 2
equation (1) 11
equivalent (1) 1
error 2
evolution 1
example 1
expansion (16) 110
exponent (7) 61
extemporaneous 1
extraction 1
factor 14
figure (4) 21
figures 4
figuring 1
fire 1
formula (1) 1
fraction (2) 25
fractions 2
freshmen 1
friction (1) 13
front 1
function (1) 1
geometry 13
gonorrhoea 1
grammar 4
gravity 1
heat 5
help 1
hydraulics 1
hyphen 1
hypothenuse 1
increase 1
index (1) 10
inefficient 4
integer 2
isosceles 1
Latin 2
letter 1
letters 1
linear 3
literal 1
logarithm 1
mathematical 1
mathematics (7) 76
mechanics 1
modification 2
modifying 1
multiple 1
multiplicand 1
multiplication 3
multiplier (3) 8
multiply (1) 3
n. 1
nine 1
noun 2
number (9) 73
numbers (1) 9
numeral 2
numerator 1
of (1) 1
one 1
partition 1
Pearson (1) 4
Pearson's 1
percentage 1
phenol (1) 2
physics (1) 4
place before 1
play 1
polynomial (1) 1
power 7
preceding 3
prefix (1) 3
probability 1
problem 1
proportion 1
psychology 2
quotient 1
radical 5
ratio 1
ration 1
refraction 6
relation (1) 5
relationship (1) 1
respiration 1
respiratory 1
restitution 1
result 2
root 2
safety (1) 1
science 1
sentence 1
sign 1
sine 1
small 1
small figure 1
small number 1
square 2
statistics 1
steel 1
studying 1
sufficient 2
suffix 1
supplement 1
smbol (1) 1
tangent (1) 15
temperature 2
term (1) 5
tetrahedron 1
theorem 1
thermal (1) 1
thesis 1
three 2
3.1416 (1) 1
together 1
triangle (1) 1
trigonometry (1) 9
two 6
united 1
unknown 1
urinalysis 1
value 1
variability (1) 3
variation (2) 5
W. 1
whole (1) 2
with 1
words 1
x 2
x2 (1) 1
zero 1

71. PERENNIAL.

Individuality Frequency, 112.

Failure Frequency, 6.

adjective		1
age		1
ages		1
almanac		1
always	(7)	24
anatomy		1
animal	(1)	2
annual	(27)	208
annually		2
annus		1
around		1
autumnal		1
beauty		1
beet		1
biennial	(4)	35
blight		1
bloom		1
botanical		1
botany		13
brain		2
brass		1
calendar		1
ceaseless		1
cedar		1
centenary		1
centigenerian		1
century		1
coming again and again		1
constant	(2)	6
continual		4
continually		2
continued	(1)	1
continuous		3
daily	(1)	2
dandelion	(1)	1
dawn		2
day		1
decennial		2
diurnal		1
diurnally		1
early		1
edge		1
election		1
enduring		1
ephemeral		1
eternal	(2)	10
eternally		1
eternity	(1)	1
eternity	(1)	1
ever	(1)	5
ever-blooming	(1)	1
evergreen		3
everlasting	(1)	35
everywhere	(1)	1
every year		1
exterior		1
father		2
fir		1
flood		1
floral		1
flower	(2)	43
flowering		1
flowers	(5)	28
forestry		1
forerunner		1
forever	(1)	25
foxglove		1
frequent		5
fruitage		1
government		1
grateful		1
green	(1)	3
growth		2
habitual		1
hardy	(1)	7
herb	(2)	3
herbaceous		1
history		1
Horace		1
immortal	(1)	1
irrigation		1
Kaiser		1
larkspur		1
lasting	(1)	10
Latin		2
law		1
leaf		1
long		1
lord		1
many		2
mathematics		1
momentary		1
mountains		1
nerve		1
nocturnal		1
oak		1
often		4
old		3
once		1
parent		1
parental		1
parents		1
parsnip		1
peas		2
perennium	(1)	1
perimeter		2
period		1
periodic		1
permanent		2
perpetual		7
Petunia	(1)	1
phlox		1
plant	(8)	45
plants	(4)	25
poetry		1
post-prandial		1
prince		1
prolonged	(1)	1
pyrene		1
Pyrenees		1
quadrennial		1
recurrent		1
recurring		5
regular		1
regularly		1
religion		2
rhythmic		1
root	(1)	1
rose		1
round		1
safety		1
season	(1)	4
seasonal		1
seasons		2
skeleton		1
spring		7
stream		1
study		1
summer		1
sun		1
temporal		1
temporary		3
thistle		1
through		1
throughout		3
throughout the year		1
time	(3)	21
together		1
tree	(2)	7
trees	(1)	3
triennial		1
tropics		1
twice		1
two		1
two ears		1
weather		1
weeds		1
wig		1
winter		2
word		1
world		1
year	(2)	78
yearly	(9)	144
years		13
youth		4
youthful		1

72. PLEBEIAN.

Individuality Frequency, 121.

Failure Frequency, 2.

adjective		1
ancient		1
Annapolis	(1)	1
aristocracy	(2)	19
aristocrat	(3)	39
aristocratic	(15)	57
aristocrats		1
army		2
assembly		1
Athenian		1
Athens	(1)	1
baker		1
barren	(1)	1
Beacon Hill		1
beggar		1
body		1
boorish		1
bourgeois		7
bourgeoisie		1
boy		1
bromide		1
B.		1
B.		1
butter		1
cadet		1
Caesar		1
Caillaux		1
caste		2
cheap		1
citified		1
citizen		9
city		2
civilian		1
civitas	(1)	1
class		6
coarse		3
college		1
common	(23)	243
commoners		1
common people		2
commonplace		6
condition		1
countrified		1
country	(1)	4
countrymen		1
crowd		1
custom		1
democracy		3
democrat		1
democratic	(1)	2
description		1
despicable	(1)	1
different		1
dirty		1
dynasty		1
East Side		1
England		2
everybody		1
farmer		6
folk		1
folks	(1)	2
food		1
fool		1
force	(1)	1
forest		1
France		2
freshman		1
fustian		1
government	(1)	1
Gracchi	(1)	2
Greece		9
Greek		3
Greeks		1
ground		1
hayseed		1
higher		1
history		11
hobo		1
hoi polloi		4
I.		1
inhabitant		1
Italians		1
janiculum		1
Julius Caesar		1
laborer		2
Latin		1
L.		1
lords		1
low	(2)	23
low caste		1
low class		1
lower		6
lower order		1
lowly		3
man		8
manner		1
Marius	(1)	1
masses		4
mathematics		1
medium		1
men		1
Mexico		1
middle		1
mob	(1)	6
Nero		1
negro	(1)	1
noble	(1)	5
ordinary	(1)	7
past		1
patrician	(10)	100
peasant		9
pedestrian		1
peon		1
people	(11)	84
person	(1)	3
Philistine		2
pilaster		1
plain		3
pleb		2
plebiscite	(2)	3
plebs		3
Plutarch		1
plutocrat		1
politician		1
poor	(4)	27
populace		1
popular		2
poverty		1
proletarian		1
proletariat		8
public		2
publican		1
ragged		1
refined		1
rich		2
ritual		1
Roman		15
Roman history		2
Roman law		1
Romans		2
Rome	(4)	61
rough		1
royalty		1
S.		1
sansculotte		1
scrub		1
serf	(1)	5
servant		1
servants		1
Shakespeare		1
simple	(1)	2
simplicity		1
Slav		1
slave	(1)	9
slaves		1
snob		1
socialism		3
sociology	(1)	2
soldier		1
sophomore		1
Sparta		1
S.		1
star		1
strong		1
toga		1
tough		1
tramp		1
tribe		2
tribunal		1
tribune		1
uncouth		1
underling		1
very low		1
vote		1
vulgar	(1)	11
walking		1
war		1
West Point		1
woman	(1)	1
work		1
workman	(1)	2

73. CATALYTIC.

Individuality Frequencey, 168.

Failure Frequency, 111.

abnormal		1
abrupt		1
acatalytic		3
accelerating	(1)	1
acceleration	(1)	1
accident	(2)	3
action	(9)	39
activator		1
activity		1
aged		1
agency		3
agent	(5)	81
agents		1
aid		3
anabolic		6
anabolism		1
anacatalytic		1
analysis		4
analytic	(13)	46
analytics		2
ancient		1
apart		2
apocalypse		1
assistance		1
assisting	(1)	2
association		1
atacatalytic		1
attraction		1
attractive		1
autocatalysis		1
awful		1
biology		2
body		1
brain		1
break	(1)	3
breakdown	(1)	1
breaking		4
breaking up		1
build		1
builder		1
building	(1)	2
cab		1
Cadillac		1
calyx		1
capacity		1
cat		6
catabolic		1
catabolism		1
cataclysm	(1)	37
cataclysmic		4
catacombs		1
catalepsis		4
catalepsy		10
cataleptic		43
catalepton		1
catalogue	(1)	3
catalysis	(1)	12
catalyzer		2
catapult		4
cataract		1
catastrophe		10
catatonic		4
catechism		4
category		1
caterpillar	(1)	1
cathode	(1)	1
Catholic		3
Catholicism		1
Catiline	(1)	6
catnip		1
cat-o-nine-tails		1
cattle		3
change		10
changing		2
chaos		1
chasm		2
chemical		7
chemical action		1
chemical process	(1)	2
chemical reaction	(1)	1
chemistry	(11)	62
chew		1
chlorophyll		1
church		1
collection		1
compact		1
condition of the earth		1
connected		1
consciousness		1
contact	(1)	1
cotillion		1
cows		1
crazy		1
current		1
cutting		1
daughter		1
decay		1
decomposition		1
derivation		1
destroy		4
destruction	(1)	9
destructive	(1)	15
diaphragm		1
dictionary		1
dietetics		1
disaster		3
disastrous		1
disease		3
dissociation		1
dissolution		1
disturbing		1
divide	(1)	1
division		1
dog		1
down		7
downfall		2
downward		1
drugs		1
earthquake		4
effect		2
electric		3
electrical		1
electricity	(2)	8
energy		1
enzyme	(7)	23
enzymes		1
epilepsy		3
epileptic		9
epileptics		1
episode		1
evolution		1
explosion		2
eye		2
fall		2
falling		2
falling down		1
falls		1
ferment		3
ferments		1
filter	(1)	1
fire		1
fit		24
fits		13
flood		1
flower		1
force		2
foreign		1
form		1
F.		1
function	(1)	2
future		1
galls		1
general		2
geology		2
gold		1
Greek		6
hard up		1
hasten		1
hastening		1
haziness		1
heat		1
help	(1)	3
helper		1
helping		1
Hindu		1
hydrolytic		1
hyperbola		1
hypnotic		1
hypnotism	(1)	2
hysteria		1
influence		2
insanity		1
ions	(1)	2
kata-		1
katabasis		1
kill		1
kitten		1
Latin		1
line		1
L.	(1)	1
magnesium		1
managese		2
manganese dioxide		2
M.		1
mathematics		1
medical term		1
medicine		1
metabolic	(1)	3
metabolism		2
militance		1
negative		1
nonsense	(1)	1
nothing		1
origin		1
O.	(2)	2
ova		1
oxidasis		1
oxidation		1
oxygen	(1)	1
ozone		1
palsy		1
patient		1
peculiar		1
person		2
physician		1
physics	(1)	8
physiology		1
pillar		1
platinum	(3)	19
pleasant		1
Poe		1
poetry		2
Popocatepetl		1
precipitate	(1)	1
precipitation	(1)	1
process	(2)	11
psychology	(1)	1
rapid		1
reaction	(5)	21
reagent	(1)	2
reversal		1
rhetoric		1
Rome		1
ruin		1
science		5
scientific		1
shock		1
sleep		2
sleepy		1
slow		1
smash		1
solution		2
spasmodic		1
speed	(2)	5
spells		2
spirit		1
spontaneous		1
stalagmites		1
starter	(1)	1
state	(1)	5
stiff		1
still		1
stimulation		1
stimulus		1
stirring		1
stroke		1
study		1
substance		1
synthetic		2
tearing down	(1)	2
terrible		1
together		2
trance	(1)	3
tube		1
universal		1
upheaval		2
velocity	(1)	2
versification		1
without		1
yawning		1

74. EMBRYO.

Individuality Frequency, 93.

Failure Frequency, 3.

adult	(4)	8
ambassador		1
amnion		1
amoeba	(1)	8
amphioxus		1
analysis		1
anascarca		1
anatomy		1
animal		9
ante		1
anthropology		1
atom		1
babe		1
baby	(3)	29
bacteriology		1
bean	(1)	5
begin		1
beginning	(1)	117
beginnings	(1)	5
biology	(1)	47
bird		2
birth	(2)	23
blastula		1
body		9
bone		1
bones	(1)	1
born		1
botanic		1
botany		4
bottle		2
boy		1
boys		1
brain		2
bud		1
cell	(4)	22
chart		1
chick	(6)	34
chicken		13
child	(2)	31
city		1
cleavage		1
cocoon		1
corn		2
course		2
curled		1
cytology		1
development	(5)	17
dog		1
early		4
ectoderm		2
egg	(10)	60
eggs		1
ego		1
elementary		1
embellish		1
embrace		1
embryological	(1)	1
embryology	(3)	26
embryonic		3
evolution		2
evolve		1
F.		1
first		5
fish	(1)	6
flower		5

foetal	(1)	2
foetus	(10)	52
form		8
formation		2
formative		1
frog		1
fundulus		1
generation		1
genesis		1
germ	(4)	45
germination		1
Greek		1
growing		1
growth		11
head	(1)	2
histology		1
hormone	(1)	1
human	(2)	15
hygiene		1
infant	(2)	9
interest		1
invertebrate		1
jar		1
J.	(1)	1
kid		1
kitten		1
laboratory	(1)	3
larva		2
L.		1
life	(3)	27
little		1
man	(2)	7
M.		1
matter		1
medicine		3
minuteness		1
mitre		1
morphology		2
M.		1
mother		3
museum		1
neural		1
new		3
newly born		1
nuclues		7
ontogeny		2
organism	(1)	3
origin	(1)	6
original		1
ova		2
ovary		1
ovum		4
paleontology		1
pallium		1
parasite		1
person		1
physiological		1
physiology		7
pig	(1)	7
placenta		1
plant		6
plantlet	(1)	1
possible		1
premature		1
primitive		2
protoplasm		1
protozoa		2
psychology		1
rats		1
reproduction		4
sac		3
science		1
section		1
seed		21
size		1
slide		1
small	(1)	28
snake		1
spore		2
sporont		1
sprout		1
stage		2
start		1
starting		1
state		1
structure	(2)	2
text-book		1
theory	(1)	1
tiny		2
tissue		2
toad-fish		1
unborn		7
undeveloped		8
unfinished		1
unformed		3
uterus	(1)	4
vertebrate		1
womb	(2)	5
worm		1
young	(6)	39
youth		3
youthful		1
zoology	(2)	21

75. SPECTRUM.

Individuality Frequency, 62.

Failure Frequency, 1.

analyses		1
analysis	(24)	94
apparatus		1
arc		2
astrology		1
astronomy		4
band		1
band of color	(1)	1
bands		1
bars		1
biology		1
blue	(1)	5
brain		1
bright		2
Bunsen		2
card	(1)	1
chart		1
chemistry	(1)	6
color	(16)	179
colors	(3)	130
crystal		1
diffraction		1
dispersion		1
division		1
divisions	(1)	1
eclipse		1
examination		1
eye		8
figure		1
Fraunhofer		2
ghost		1
ghosts		1
glass	(2)	26
green		1
human		1
inspect		1
instrument		2
iron		1
laboratory		1
lecture		1
lens		3
light	(18)	206
line		1
lines	(2)	6
looking		1
mercury		1
microscope		3
mirror		1
M.		1
Newton	(1)	2
oculist		1
optician		1
optics		1
orange		1
petrography		1
photograph		1
physics	(3)	51
physiology		2
pigment		1
polariscope		1
prism	(3)	29
psychology		1
purple		1
radium		1
rainbow	(4)	34
ray	(1)	4
rays	(1)	8
read		1
rectum		1
red		9
refraction	(2)	3
scale		1
science		1
seeing		1
S.		1
sight		9
sky		1
sodium	(1)	3
solar	(2)	17
spectacle		4
spectacles		1
spectacular	(1)	2
spectator		2
spectral		3
spectre		3
spectograph		1
spectroscope	(2)	16
star	(1)	3
stars		2
sun	(5)	47
sunlight	(1)	1
thesis		1
urine		1
variegated		1
violet		1
violet rays		1
visible	(1)	2
vision		1
waves	(1)	1
X-ray		1
zoology		2
Zurich		1

76. CONTINENT.

Individuality Frequency, 53.

Failure Frequency, (1) 1.

abstainer	(1)	1
Africa	(2)	25
America	(18)	206
American		4
area	(1)	2
Asia	(1)	37
Atlantis		1
Australia	(1)	18
bigness		1
birth		1
body		2
bound		1
candy		1
cape		1
complete		1
connected		1
conscience	(1)	1
conscious		1
contain		1
contained		1
content		1
contents		2
continence		1
continual		1
continuity		2
continuous		1
contrive		1
countries		2
country	(2)	25
definition		1
division		3
earth	(1)	18
England		1
Europe	(6)	112
European	(1)	5
expanse		1
extent		1
federal		1
fibers		1
geographical		1
geography	(3)	47
geology		1
Gibraltar		1
globe	(2)	7
government		1
half world		1
hemisphere	(4)	10
impotent		1
incontinent		3
island	(28)	90
islands		1
land	(12)	156
land-mass		1
large	(1)	12
largeness		2
largest		1
lost		1
Magellan		1
map	(2)	32
mass		1
moon		1
mountain		2
nation		3
North America	(6)	45
ocean	(2)	19
oceans		2
peninsula		5
physiography		1
religion		1
restraint		2
same		1
science	(1)	1
sea		7
section		1
shape	(1)	3
shelf		1
shore		2
six		2
size		2
South America		4
space		1
sphere		1
stars		1
strand	(1)	1
subdivision		1
territory		1
theorum		1
United States		3
Utica		1
vast		1
war		2
water		4
western	(1)	6
whole		4
wide		1
world		7

77. SPORE.

Individuality Frequency, 123.

Failure Frequency, 21.

Africa		2
agamogenesis	(1)	1
algae		1
algebra		1
amoeba		3
anatomy		1
animal		5
anthrax		2
arm		1
bacilli		1
bacillus		4
bacillus subtilis	(1)	1
bacteria	(8)	31
bacteriology		10
bacterium	(1)	6
ball		5
bearing	(2)	4
beginning		4
biology		47
biophore		1
bit		1
black		2
blood		1
body		1
boor		1
bore		1
botany	(2)	51
breathing		1
bred		1
bred		1
bud	(1)	3
bug	(1)	1
bugs		2
burst		2
case		2
cedar		1
cell	(5)	31
cells		1
circle		1
cocci		1
composer		1
coral		1
covering		1
cryptogam		1
cryptogram		1
cryptograms		1
develop		1
difficulty		1
door		1
dot		1
dots		1
dry		1
dust	(2)	6
egg		20
eggs		4
element		1
elephant		1
embryology		3
encapsulated		1
equisetum	(1)	3
explore		1
fermentation		1
fern	(12)	87
ferns		7
fertilization		1
fish		16
flagellum		1
flower	(3)	23
flowers		6
foot		1
form		2
formation		1
forming		2
frog		1
frogs		1
frond		1
fruit		1
fungi		3
fungus	(1)	14
gamete		1
generation		1
George		1
germ	(7)	37
germinate		1
germination		2
green		1
growth		3
gymnaspore		2
H.		1
hand		1
hole	(1)	11
hoof		1
hunting		1
impalpable		1
imperfection		1
individual	(1)	1
indusium		1
infusoria		1
insect		1
invertebrate		1
jelly		1
jelly fish		1
Latin		1
leaf		1
life		5
little		1
low life		1
lycopod	(1)	1
medusa		1
megaspore		1
microbe		1
milk		1
minute	(1)	3
moss		3
mould		11
moulds		1
movement		1
mucor		1
mushroom	(3)	18
mushrooms	(1)	2
nucleus		1
organism		1
ova		1
part	(1)	2
perennial		1
phrase		1
picker		1
pig		1
pine		2
plant	(10)	60
plants	(2)	8
pollen	(4)	18
pollywog		1
pond		1
pore	(1)	5
powder		1
prickle	(1)	1
process		1
projecting		1
propagation		1
protozoa		3
Pteris		1
reproduction	(2)	19
Rome		1
roommate		1
round	(1)	4
round body		1
sac		1
scale	(1)	1
science		5
seed	(16)	114
skin		3
sleep		1
small	(1)	12
smallness		1
snow		1
source		1
South Africa		1
spa		1
spear		1
speck		2
sperm	(1)	8
spermatozoa		2
sphere		1
spike		1
spine		1
splore		1
Spohrfieder		1
spoke		1
sponge		6
sporadic		11
sporangium		3
sporophite		1
sporophyll		1
sporozoa		1
sporozoon		2
sport		10
spot		1
stem		2
tetanus	(1)	3
trace	(1)	6
track		5
tracks		2
trail		1
tree		2
tube		1
unicellular life		1
unit		1
water		1
whole		1
wind	(1)	1
worm		1
yeast		8
young		2
zoology		18
zoophite		1
zoospore		1
zygote		1

78. THEOREM.

Individuality Frequency, 67.

Failure Frequency, 4.

abstract	(1)	2
algebra	(2)	64
algebraic		2
all		1
analysis		1
answer		1
arithmetic	(1)	8
Avogadro		1
axiom	(1)	8
belief		1
binomial	(15)	123
biology		1
blackboard		2
book		2
calculation		1
calculus		4
cause		1
chemistry		2
conclusion		1
condition		1
connote		1
conundrum		1
corollary	(2)	11
demonstrate		1
demonstration	(3)	6
diagram		1
equality		1
equation	(1)	10
established		1
Euclid	(2)	7
example		4
exercise		1
explanation		2
fact		1
false		1
fierce		1
first		1
formula		1
generalization		1
geometric	(1)	1
geometrical		4
geometry	(26)	327
guess		2
H.		1
hypothesis	(3)	32
idea	(1)	5
imaginary	(1)	2
imagination		1
indices		1
interrelation		1
italics	(1)	1
law		3
L.		2
lessons		1
line		1
logic	(1)	1
M.		1
mathematics	(9)	77
maxim		2
maximum		1
memorized		1
mutation		1
nebular		1
Newton	(1)	2
notion		1
old		1
original		1
π		1
part		1
physics		1
pons asinorum		1
postulate	(1)	3
practical		1
practice	(1)	2
principle	(1)	5
problem	(3)	45
proof	(4)	22
proposition	(8)	60
prove		5
Pythagoras		3
Pythagorean		2
question		1
rule		5
school		3
science		2
sentence	(2)	3
Spinoza		1
square		1
statement		8
study		1
supposition		1
syllabus		1
tarlagtia		1
Taylor's	(1)	1
teacher		1
theater		3
theme		1
theocracy		1
theology	(1)	1
theorize		1
theory	(3)	34
thesis		1
thinking		1
third		1
thought		2
thiangle	(1)	3
triangles		1
trigonometry	(1)	1
truth		4
two		1
version	(1)	1
words		1
work		1

79. HIMALAYA.

Individuality Frequency, 67.

Failure Frequency, 2.

A.	1
aeroplane	1
Africa	1
Allegheny	1
Alps	4
altitude	1
Andes	3
A.	1
Ararat	(1) 1
Asia	(6) 61
beauty	1
bees	1
black	1
blackberry	1
blood	1
Buddhism	1
B.	(1) 1
Carpathian	1
China	(1) 4
climbing	1
cocoanut	1
cold	2
continent	1
country	(1) 5
distant	1
elevation	1
enamel	(1) 1
Europe	2
Everest	(4) 15
F.	1
folding	1
foreign	1
Ganges	1
geography	(1) 12
giants	1
gigantic	1
girl	1
glacier	1
goat	1
goats	1
Greece	2
haemolysis	2
hard	1
Hawaii	(1) 1
Hayti	1
height	13
hiems	1
high	(1) 4
highest	3
Hindu	1
Hindustan	(1) 2
H.	1
hymn	1
hymnology	1
hymns	1
India	(12) 78
Indus	(1) 1
island	3
islands	1
isthmus	1
Kim	1
Kipling	2
L.	1
land	1
L.	1
large	1
Malay	1
map	2
mountain	(33) 307
mountains	(31) 367
Mount Everest	6
Oceanica	1
natives	1
Nepal	1
nigh	1
peaks	(1) 4
pen	1
peninsula	2
Pike's Peak	1
plant	1
Popocatepetl	1
rabbit	3
race	1
range	(1) 5
rocks	1
Russia	1
snow	(1) 11
snow caps	1
space	(1) 1
state	1
steep	1
sublime	1
Thibet	7
volcano	1
white	1

80. RENAISSANCE.

Individuality Frequency, 116.

Failure Frequency, 1.

age	(1) 13
ages	1
ancient	1
antiquity	1
architecture	(1) 17
art	(8) 89
arts	1
awakening	(2) 15
barbaric	1
bas relief	1
beginning	2
birth	(2) 9
book	(1) 1
books	1
Botticelli	1
brightness	1
building	1
buildings	(1) 2
cathedral	2
Catholicism	1
Cellini	1
centuries	1
century	2
Cervantes	1
change	4
church	1
Cimabue	1
class	1
classics	1
Caleb	1
Columbus	1
culture	7
Dante	9
dark ages	1
date	1
Da Vinci	(2) 5
development	(1) 1
doily	1
early	(1) 2
education	6
Egypt	1
Elizabethan	1
England	3
English	8
enlightenment	2
epoch	2
era	4
Erasmus	2
Europe	(2) 20
European	(1) 1
fascinating	1
feudal	1
feudalism	(1) 2
fifteen hundred	1
fifteenth	1
fifteenth century	1
Florence	6
Fontainebleau	1
fourteen hundred	1
fourteen fifty-three	1
France	(4) 74
freedom	1
French	(1) 25
French Revolution	1
furniture	(1) 1
Galileo	(1) 2
genetic	(1) 1
Germany	2
Giotto	1
Giottesque	1
gothic	4
G.	1
Greece	(1) 2
Greek	1
growth	1
Heidelberg	1
history	(9) 70
Holland	1
hotel	1
Italian	(1) 25
Italians	1
Italy	(13) 86
kings	1
knighthood	1
lace	(1) 12
late	1
Latin	1
learning	(2) 34
lecture	1
Leonardo	3
Leonardo DaVinci	1
letters	(1) 2
life	1
literary	1
literature	38
literature and art	1
L.	1
Luther	(1) 7
luxury	1
Machiavelli	1
map	1
Matthew Arnold	1
mediaeval	16
mediaevalism	(1) 1
Michael Angelo	(2) 8
middle ages	(5) 14
Milton	1
monks	1
movement	1
music	1
Napoleon	1
new	(1) 7
new birth	(2) 4
newness	1
nothing	1
old	3
painting	(1) 13
paintings	2
Paris	1
Pater	1
period	(6) 77
Petrarch	(1) 4
philosophy	2
picture	(1) 2
poet	1
poetry	(1) 3
poets	1
Portugese	1
previous	1
printing	(1) 2
procession	(1) 1
progress	1
Rabelais	1
Raphael	(1) 4
rebirth	(3) 13
reborn	2
recollection	1
reconstruction	1
recovery	2
reform	2
Reformation	(2) 22
reign	1
rejuvenation	1
Rembrandt	2
renascence	1
renew	1
renewal	9
republic	(1) 1
restoration	(1) 1
resurrection	1
retrograde	1
review	1
revival	(1) 21
revolution	(2) 2
Richelieu	1
rings	1
rising	1
R.	(1) 2
rococo	(1) 1
romanticism	2
Rome	1
Savonarola	2
school	1
sculpture	1
Shakespeare	6
soldiers	1
Spanish	1
spelling	(1) 2
Spinoza	1
spirit	1
Symonds	(1) 5
text book	1
theory	1
thought	1
time	4
Titian	2
twelve hundred A. D.	1
upheavel	1
Valla	1
Velasquez	1
Voltaire	1
Walter Pater	(1) 3
war	1
writers	1
writing	1
writings	1
year	1
youth	1

81 QUOTIENT.

Individuality Frequency, 52.

Failure Frequency, 0.

addition	(1) 4
algebra	(1) 15
answer	(1) 41
answers	1
antecedent	1
arithmetic	(7) 117
arithmetical	1
brother	1
calculating machine	1
carbon	1
coefficient	(1) 14
cosine	1
cotangent	1
deficient	1
denominator	(1) 4
difference	1
divide	(3) 14
dividend	(3) 67
dividing	5
divider	1
divisible	1
division	(16) 267
divisor	(26) 152
end	1
equal	3
equality	1
equation	4
equator	1
equivalent	1
example	(1) 2
factor	5
figure	(1) 2
figures	4
figuring	(1) 1

finish		1
fraction	(5)	29
fractions		6
geography		1
geometry		4
grammar		1
indicator	(1)	1
language		1
less		1
line	(1)	1
many		1
mathematical		1
mathematics	(5)	35
measurement		1
multiplicand	(2)	3
multiplication	(2)	4
multiplier	(1)	2
multiply		2
multiplying		1
number	(3)	16
numbers	(1)	7
numerator		1
outcome	(1)	1
part	(1)	4
portion		1
predicate		1
problem		2
product	(4)	31
purity		1
Q.		1
question		1
quorum		1
quota		2
quotation		1
quote	(1)	1
ratio		4
recollection		1
relation		1
remainder		11
remaining		1
respiration	(1)	3
respiratory	(2)	3
result	(2)	40
school		5
sign		1
subtraction	(1)	3
sum	(1)	10
tangent		2
tests		1
theory		1
third		1
together		1
total		1
two		1
under	(1)	1
vision		1
whole	(1)	1
write		1

82. OXIDATION.

Individuality Frequency, 98.

Failure Frequency, 4.

acid		2
acids		1
action		2
agent		1
air	(1)	40
analysis		3
atmosphere		1
automobile		1
black		2
blackening		1
blood	(1)	11
botany		1
brass		2
breaking up		1
break up		1
breathe	(1)	2
breathing	(1)	6
bubbling		1
burn		12
burning	(8)	82
carbon	(1)	6
carbonization		1
catalytic		1
cell		1
cells		1
change		8
chemical	(1)	9
chemicals		2
chemistry	(15)	130
color		1
combine		1
combustion	(1)	10
conflagration		1
consumption		2
copper	(1)	6
crystals		2
dark		1
decay		1
decomposition		1
dehydration	(1)	4
deoxidation	(1)	3
desiccation		1
destroy		1
destruction		1
dew		1
dietetics		1
digestion		1
dissociation		1
division		1
dry		1
earth		1
east		3
electrolysis		1
energy		1
European		1
evaporation		1
experiment		1
exposure		1
fermentation		1
fire	(2)	19
fitters		1
fizz		1
flame	(1)	2
food		3
foundation		1
gas	(2)	10
geology		1
gold		1
gun metal		2
heat		8
H_2O_2		1
hydrate		1
hydration	(1)	6
hydrogen	(2)	13
ionization		1
iron	(1)	37
iron rust		1
jewelry		1
killing		1
knife blade		1
laboratory		4
Lavoisier		1
layer	(1)	1
lead		1
life	(1)	3
light		3
liquefaction		1
liquefy		1
L.		1
lungs		1
mathematics		1
medicine		1
metabolism	(1)	1
metal		4
metals		2
mineralogy		1
muscle		1
neutralization		1
new life		1
nitrate	(1)	1
nitric acid		1
nitrogen	(1)	4
occident		8
occidental		5
operation		1
orient		3
oriental		2
orientation		5
oxalic		2
oxide		7
oxidize		5
oxygen	(17)	132
ozone		1
peroxidize		1
peroxide		1
petrify		1
physics		6
physiology		5
potassium		1
P.		1
Priestley		1
process	(3)	24
processes		1
products		2
progress	(1)	1
purification		3
purse		1
putrefaction	(1)	1
putter		1
rain		1
reaction	(3)	5
red	(1)	4
reducing		1
reduction	(13)	88
R.		1
respiration	(1)	1
result		1
rocks		1
rust	(11)	74
rusting		4
science		4
scientific		1
sewage		1
sidereal		1
silver		17
steel		1
strangulation		1
sulphur		1
sun		1
sunlight		1
tanks		1
tin		1
tissue		3
union		1
ventilation		3
vigor		1
water	(1)	13
welding		1
west		3
western		1
yeast		1
zinc	(1)	2

83. HAEMOGLOBIN.

Individuality Frequency, 85.

Failure Frequency, 71.

active		1
adrenalin		1
advertisement		1
agglutination		1
albumen		1
amoeba		1
anaemia		1
analysis		1
anatomy		2
animal		2
assimilation		1
B.		1
beef juice		1
biology	(1)	16
black pill		1
blood	(84)	619
blood-curdling		1
blood substance		1
body		2
botany		3
brain		1
carbon dioxide		1
cell		2
chemical		3
chemicals		1
chemistry	(1)	17
chlorophyll	(1)	2
Choctaw		1
classroom		1
coagulate		1
coagulation		1
color		7
coloring		1
corpuscle	(1)	12
corpuscles	(1)	4
crystals		1
deviation		1
dietetics		2
doctor		1
drop		1
element		1
entomology		1
fat		1
fibrin		1
figure		1
fluid		2
food		5
German		3
germs	(1)	1
ghost		1
glauben		1
globe		9
G.		1
globular		2
globule		4
globules		2
gluttonous		1
goblins		1
G.		1
Greek		1
green		1
haematin		1
haematite		1
haematococcus		1
haematoporphyrin		2
haemoglobinometer		1
haemolysis		1
half		5
half globe		1
hemisphere	(1)	15
hemispherical		1
hemorrhage		2
heterogeneous		1
Himalaya		1
Himalayas		1
H.		1
home		1
homogeneous		2
hospital		1
humility		1
hymen		1
hymeneal		1
incomplete		1
ion		1
iron	(1)	7
jelly		2
laboratory		1
leaf		1
lecture		2
leucocytes		1
light		1
meat		1
medicine		10
milk		3
nutrition		1
orange		1
organic		1
O.		1
oxygen		3
oxyhaemoglobin	(1)	1
philosophy		1
physics		1
physiology	(3)	19
plant		1
plasma		1
pollywog		1
protein		1
protoplasm		1
quinine		1
red	(4)	25
scale		1
science		6
scientific		2
serum		2
shape		1
smell		1
stain		3
substance		3
Sunday papers		1
Tallquist		2
teacher		1
test		4
tuberculosis		1
winter		1
world		1
yellow		1
yolk		2
zoology		3

84. AXIOM.

Individuality Frequency, 76.

Failure Frequency, 4.

accident		3
adage		1
algebra	(1)	29
answer		1
apparent		2
a priori		1
argument	(1)	1
arithmetic	(2)	7
assumption		4
axe		3
A.		1
axiomatic		6
axis		4
axle		1
belief		1
book		1
B.		1
B.		1
certain		2
certainty		1
class		1
coagulate		1
common	(1)	1
commonplace		2
conclusion		1
corollary		14
correct	(1)	3
demonstration		1
easy		3
epigram		1
equal		1
equals		2
equivalent		1
established		1
Euclid	(1)	8
evidence		2
evident		5
example		2
explanatory	(1)	1
expression		1
fable		1
fables		1
fact	(1)	13
figures		1
first		1
fundamental		3
geometrical		1
geometry	(22)	209
grammar		2
granted		2
hard		1
H.	(1)	1
hunger		1
hypothesis		1
idiom		4
immortality		1
Kant		2
know		1
knowledge		1
known		2
law		12
line		1
logic	(1)	7
mathematics	(4)	35
maxim	(1)	3
meaning		1
morals		1
motto		3
mottoes		1
naturally		1
noun		1
obvious	(1)	2
old		1
one	(1)	2
paradigm		1
perimeter		1
philosophy		3
phrase		3
plain		1
Pope		1
postulate	(7)	30
precept		1
principle	(2)	12
problem		2
proof	(6)	20
proportion		1
proposition	(1)	11
prove	(1)	2
proved		1
proverb		7
q. e. d.		1
quotation		1
reason	(1)	1
rhythm		1
right		1
rule	(1)	28
same		1
sane		1
saying	(1)	12
self evident		16
Seneca		1
sentence		1
short		1
simple		1
simplicity		1
six		1
stability		1
statement	(2)	14
straight		1
sure		3
surety		1
task		1
teacher		1
ten		2
text book		3
theology		1
theorum	(15)	85
theory	(2)	15
thought		1
trigonometry	(1)	2
trite		2
true	(1)	15
truism	(1)	8
truth	(17)	223
two		1
understood		1
undisputed		1
vaccination		1
variation	(1)	1
verb		1
word		1
worth		1

85. AMAZON.

Individuality Frequency, 81.

Failure Frequency, 0.

Africa		1
A .		1
Alps		1
amazement		1
America	(1)	2
amethst		1
Andes		1
ancients		1
animals	(1)	1
arm		1
Asia		1
battles		1
B.		1
belt		1
big		6
B.		1
black		1
Bohemian		1
brave	(1)	2
brazen		1
Brazil	(7)	49
bronze		1
Bruenhilde		2
burlesque		1
cannibal		1
club		1
Colonel Roosevelt		1
colored		2
coon		1
distant		1
dress		1
ding		1
fair		1
female	(1)	4
fight		1
fighter		1
fighters		1
fighting		1
fine		1
flowing		1
forest		2
F.		1
fresh water		1
geograph		7
giant		1
giantess		1
girdle		1
Goethe		1
Greece	(2)	5
Greek		2
Greeks		1
gulf		1
Hippolyte		3
histor		4
Homer		1
horizontal		1
horse		1
horses		1
huge		2
Iliad		1
Indian		2
island		1
jungle		1
lady		5
large		7
Latin		1
longest		1
lovely		1
maiden		1
mighty		1
missionary		1
Mississippi		1
mountain		1
mythology		3
negro		2
Nile	(1)	2
ocean		2
Orinoco		1
pampas		1
Pankhurst		1
para	(1)	1
parrot	(1)	1
Parthenon	(1)	1
Penthesilea		2
person		1
Pinero		2
powerful		2
queen		6
race		3
riding		1
river	(54)	426
rivers		2
Roosevelt	(2)	31
sculpture		1
sexless	(1)	1
ship		1
size		3
soldier		1
south		1
South America	(6)	60
South American		1
statue	(1)	4
stone	(1)	1
stream	(1)	1
strength		5
strong		4
suffragette	(2)	4
tall		1
Teddy		1
trees		1
valley		2
vegetation		1
waitress		1
Wallace	(1)	1
war		1
warlike		1
warrior	(1)	7
water		2
woman	(12)	212
women	(1)	27
zone		1

86. ISOSCELES.

Individuality Frequency, 36.

Failure Frequency, 6.

acid	(1)	1
acute	(1)	1
Aeschylus		1
algebra		1
angle		1
angles		1
angular		1
balanced		1
blackboard		1
chemistry		1
drawing		1
equal	(9)	63
equal angle		1
equality		4
equal-legged		1
equal-sided		1
equiangular	(1)	2
equilateral		11
Euclid		1
even		3
figure		2
generalization	(1)	1
geometry	(3)	35
Greek		3
height		1
hexagon		1
Holmes		1
icicle		2
isoderm		1
isomerism		1
isometric		1
large		1
legs		1
like		1
mathematics		4
point		1
pointed		1
pyramid		2
Pythagoras		1
rectangle		1
rectangular		2
roof		1
same	(1)	1
scalene		3
sides		1
square		1
stately		1
Theocritus		1
three		2
triangle	(81)	811
triangles		4
triangular		1
trigonometry	(2)	3
two		2

87. COHESION.

Individuality Frequency, 111.

Failure Frequency, 3.

absorption		1
addition		1
adhere	(1)	10
adherence	(3)	11
adhering		4
adhesion	(27)	274
adhesive		2
adnation		1
affinity	(1)	1
aggregation	(1)	1
agreement		1
amalgamation		1
apart		1
atom	(1)	1
attach		2
attracting		1
attraction	(5)	17
binding	(1)	1
biology		1
blackboard		1
block		1
blood		4
brass		1
bump		1
capillarity	(1)	1
capillary		2
cement		1
chalk		1
chemistry	(1)	18
cling		1
clinging		4
close		1
coagulate		1
coagulation		2
coalesce		1
coapt		1
coefficient		1
coercion		1
cohabitate		1
cohere		1
coherence	(1)	2
coherent	(1)	6
collection		1
combination		1
coming together		1
community		1
compact		1
confusion		1
connection		3
contract		1
cosmic		1
diffraction	(1)	1
diffusion		2
disassociation	(1)	1
drops		1
ear		1
efferent		1
elastic		1
emphasis		1
exclusion		1
expansion	(1)	5
experiment		1
fast	(1)	1
fastened		1
fate		1
firmness		2
fixation		2
fixed		1
force	(6)	19
forces		2
friction		2
fusion		2
gathering		1
geology		1
glass		5
glue	(2)	31
glueing		1
gluey		1
great		1
gum		2
hang		1
hang together		1
hatred		1
heat		3
hold		2
holding		2
illustration		1
incoherent		1
intestines		1
join	(1)	2
joining		4
juxtaposition		1
Latin		1
L.		1
life		1
logic		1
magnet		1
magnetic		1
magnetism		1
marriage		1
mass		3
materials	(1)	2
matter	(1)	5
medicine		1
mercury		1
metals		1
molasses		5
molecule		6
molecules	(1)	10
mucilage	(2)	12
mud	(1)	2
occlusion		1
operation		2
opposed		1
particle		1
particles	(1)	5
parts		1
paste		2
phenomenon		1
physics	(8)	52
physiology		2
plaster		7
plates		1
power		1
protrusion		1
pull		2
pulling		1
putting together		1
repulsion		3
rubber		1
same		1
science		2
scientific		1
separation		1
shave		1
skull		1
snow		1
society		1
solid		1
sore		1
stagnation		1
stamp		4
stick	(6)	95
stickiness	(3)	10
sticking	(13)	108
sticking plaster		1
sticking together		7
stick-to-it-iveness		2
stickum		1
sticky		6
strength		4
stringent		1
stuck		1
substance		1
tape		1
themes		1
tight		1
together	(2)	55
tube		1
uniformity		1
union	(1)	13
unit		1
unite		1
uniting		1
unity		3
viscosity		1
water	(1)	9
wax	(1)	1
welding		1
wireless	(1)	1
with		1

88. PROTOPLASM.

Individuality Frequency, 109.

Failure Frequency, (1) 5.

albumen	(1)	8
alive		1
amoeba	(9)	77
analysis	(1)	1
anatomy		2
ancient		2
animal	(3)	14
animals		2
atheism		1
atom		1
baby		1
bacteriology		1
basis		1
beginning		9
beginnings		2
biology	(4)	80
bioplasm	(1)	1
blood	(2)	51
bloody		1
body	(1)	6
botany		10
brain		1
bromide	(1)	1
bugs		1
carbon		1
cataclysm		1
cell	(14)	91
cell-life		1
cells	(4)	16
cell sap		1
cellular		1
chasm		1
chemistry	(2)	2
child		1
chlorophyll		1
chromosome		2
clear		1
colloid		1
colorless		1
complex		1
constituent		1
C.		1
cytoplasm		2
cytoplasma		1
Darwin		5
divinity		1
division		1
drawing		1
earth		1
egg	(2)	9
elemental		1
elementary	(1)	3
embryo		2
embryology		2
endoderm		1
environment		1
evolution		2
first	(1)	7
F.		1
flesh	(2)	9
fluid	(2)	8
foam	(1)	1
food		3
form		2
formation		1
former life		1
gelatin		1
gelatinous		3
germ		13
germinology		1
germ plasm		1
G.		1
globule		1
glue		1
granules		1
gray		2
green		1
green leaves		1
growth	(1)	1
haemoglobin		1
histology		2
human		2
Huxley	(1)	5
inert		1
infinitesimal		1
irritability		1
jelly	(5)	54
jelly-fish		2
knife		1
leaves		1
life	(14)	142
life matter		1
liquid		2
living		6
living matter		1
lower		1
mass		8
material		2
matter		16
medicine		1
membrane		1
metabolism	(1)	3
metazoon		1
microscope	(1)	5
minute		1
molecule		1
move		1
movement		1
muscle		1
mush		1
mussy		1
myxomycete		1
nitella		1
nitrogen	(2)	4
nothing		1
nucleus		7
number	(1)	1
organism	(2)	7
origin	(1)	5
original		1
origins		1
oyster		1
paleontology		1
paste		1
philosophy		1
physical		1
physiology		12
plant	(2)	8
plants		6
plasm	(1)	3
plasma		1
plaster		1
plastic		1
plastidule		1
prehistoric		1
primary material	(1)	1
primeval		1
primitive		6
primordial		1

protean		1
proteid	(1)	5
protein	(1)	7
protozoa	(1)	16
protozoon	(1)	11
pseudopod		1
psychology		2
pulp		1
sap		1
science		3
serum		1
simple	(1)	5
skin		3
slime	(1)	2
slimy	(1)	1
small		1
soft		3
somoplasm	(1)	1
sperm		1
squashy		1
starch		2
sticky		2
S.		1
structure		3
stuff	(1)	2
substance	(3)	31
term		1
tiny		1
tissue		6
transparent		1
tree		1
unknown		1
viscous		2
vitalists		1
wabbly	(1)	1
water		3
Weismann	(1)	1
wetness		1
white		3
work		1
worm		1
woze		1
zoology		21

89. CENTRIFUGAL.

Individuality Frequency, 80.

Failure Frequency, 0.

acceleration		1
action	(1)	1
analysis		1
apparatus		1
approach	(1)	1
astronomy		1
attraction		2
away	(1)	4
axiomatic		1
axle		1
biology		1
blood		1
body		2
center		36
center force		1
central		7
"centrif"		1
centrifuge	(1)	15
centripetal	(27)	173
churn		1
circle		12
circular	(1)	7
circumference		3
concentrate		1
converging		1
cream		2
creamery		1
cream separator		2
curve		1
dairy		1
diagram		1
driven		1
earth	(1)	4
eccentric		2
experiment		1
flank wheel		1
fleeing		3
flight		2
fly		6
flying	(5)	17
flying off		1
flying out	(1)	1
fly wheel		1
force	(33)	448
forces		2
forward		1
from		2
fugue		1
geometrical		1
gravitation		3
gravity	(1)	2
grindstone		1
heart		1
heat		1
hold		1
hold together		1
hundred		1
hundredth		1
hydraulics		1
illustration		1
in		1
inward		3
jump		2
light		1
machine	(6)	14
machinery		1
mathematics		1
mechanics		1
middle		1
milk		2
misnomer	(1)	1
motion	(3)	13
movement	(1)	1
mud		1
neurones		1
off		1
out	(1)	3
out from		1
outward	(2)	4
paddle		1
perimeter		1
peripheral		1
physics	(1)	42
planetary		1
power		2
precipitate		1
pull		2
pulling		1
pump	(2)	4
rapidity		1
revolution		1
revolving		2
ring		1
rotating		1
rotation	(2)	7
round		3
science		1
sediment		1
seeking the center		1
separate		1
separation		1
separator	(1)	5
sling		1
speed		5
sphere		2
spinning		2
stone		2
string		3
sugar		1
swinging		1
swirling		1
tangent		2
tangential		1
throw		1
top		1
toward		1
turn		1
turning		1
universe		1
up		1
urine		1
water		1
wheel	(3)	21
whirl	(1)	5
whirling	(3)	14
working		1
world		1

90. MOLECULE.

Individuality Frequency, 62.

Failure Frequency, 3.

air		1
amoeba		4
analysis	(1)	1
animal	(1)	6
animals		1
atom	(47)	463
atoms		13
attraction		2
ball	(1)	2
beginning		1
big		1
biology		10
blood		2
body	(1)	5
botany		1
brain		1
brick		1
carbonic acid	(1)	1
cell		3
chemistry	(10)	84
circle		1
combination	(2)	3
composition		1
compound		1
compression		1
corpuscle		1
diminutive		1
division		2
dot		1
drop		1
dust		2
dynamic		1
election	(2)	3
element		4
enzyme		1
expansion		1
fathom		1
fish		1
force		1
form		2
gas	(1)	1
germ		3
granule	(1)	1
hypothesis		2
hypothetical		1
imaginary	(1)	1
infinitesimal		4
invisible	(1)	1
ion		6
ions		1
iron	(1)	1
law	(1)	1
life		2
little		12
mass		2
matter	(3)	34
microscope		1
minimum		1
minute	(1)	6
minuteness		2
mole	(1)	2
molecular	(1)	6
molecular weight		1
moles		1
mollusc	(2)	8
mollycoddle		3
molybdenum		1
motion		2
mouse		1
number	(1)	1
object		1
oxygen		1
oyster		1
part		7
particle	(8)	32
particles		2
philosophy		1
physics	(1)	38
picture		1
plant		2
playful		1
point	(1)	1
pollywog		1
portion	(1)	2
protein		2
protoplasm		3
science		1
scientific		1
simple		1
single		1
size		2
small	(5)	90
small atom		1
smallest		3
smallness		4
small particle		1
speck		6
specks		1
sphere	(1)	5
spot		1
stone		1
structure		2
substance		2
sugar		1
tension		1
theory		2
tiny		9
two		1
ultimate	(1)	1
uncutable		1
unit		6
units		1
vortex		1
water	(1)	10
zoology		2

91. COTYLEDON.

Individuality Frequency, 91.

Failure Frequency, (1) 139.

analysis		1
anatomy		1
angiosperm	(1)	1
animal		1
bean	(8)	76
beans	(2)	8
biology	(1)	7
blade		1
bone		1
botanical		4
botany	(8)	105
bud		1
butter		4
butterfly		1
cardboard		1
cart		1
carthage		1
cartilage	(1)	8
cat	(1)	1
cataclysm		1
catalytic		1
catastrophe		1
Catiline		4
Caucasus		1
cauterize		1
cell	(1)	3
Ceylon		1
chemical		1
chemistry	(1)	6
chlorophyll		1
class		1
cochineal		1
coddle		1
collodium		2
colloid		1
colloids		1
colytic	(1)	1
conifer		1
connective		1
corn		5
cotillion		2
cottage		1
cottolene		13
cotton	(1)	11
cotton seed		2
cotton wood		1
cow		1
darkness		1
die-	(1)	1
dicotyledon	(1)	24
dicotyledonous		2
dictionary		2
difficult		1
embryo	(1)	6
embryology		1
endogenous		1
eye		1
figure		3
flower	(8)	86
flowers		9
fluid		1
food		1
F.		1
Galveston		1
geology	(1)	1
geometry	(1)	4
germination		1
grease		1
Greek		3
green		1
ground		1
half		2
halves		1
hypocotyledon		1
ignorance		1
infant		1
jar		2
kernel		1
lard		6
lard bucket		1
leads		1
leaf	(12)	59
leaves	(1)	12
life		2
lily	(1)	1
lima bean		1
linen		1
mammoth		1
maple		1
mathematics		1
medical		2
medicine		2
mollycoddle		1
monocotyledon		3
monocotyledonous		8
nothing		1
oil		4
one		1
page		2
part	(1)	1
pea	(1)	3
petal		2
physiology		1
pine		1
pine tree		1
pistil	(1)	1
piston		1
placenta		2
plant	(24)	131
plants	(1)	8
plumule		2
pollen		1
polycotyledon		2
polyhedron		1
powder		1
prehistoric		1
root	(1)	1
round		1
science		3
seed	(13)	92
seed leaf		1
seedling	(1)	4
seeds		2
shell	(1)	2
side		1
sided		1
skeleton		1
species	(1)	1
spore		1
spreading		1
spring		1
stem		1
substance		1
sugar		1
teacher		1
technical		2
temerity		1
tendon		1
tree		4
two	(1)	6
T.		1
young plant		1
Yser	(1)	1
zoology		2

92. ABSCISSA.

Individuality Frequency, 98.

Failure Frequency, (1) 107.

abscess	(2)	65
abscission		1
absence		4
absent		5
absinthe		6
absorb		1
abstract		1
abysmal		1
abyss		6
Abyssinia		4
Abyssinian		1
across		2
Africa		1
algebra		11
analytic		1
analytic geometry		4
analytics	(1)	11
angle		1
angles		1
apart		1
arithmetic		6
astronomy		1
axes	(1)	3
axis		5
bacteriology	(1)	1
base		3
biology		1
botany		4
bottom		1
brain		1
brother		1
calculus		3
Cartesian		2
characteristic		1
chart	(1)	2
charting		1
charts	(1)	2
Charybdis		1
chasm		2
chirurgy		1
circle	(1)	4
classroom		1
coefficient		1
college		1
comet		1
conic		1
coordinant	(1)	3
coordinate	(6)	40
coordinates	(1)	6
country		2
crevice		1
cross		2
cross section		1
curve	(5)	14
cut	(1)	13
cutting	(1)	9
departure		1
depth		1
Descartes	(1)	1
description	(1)	1
diagram	(1)	3
diagrams		1
diameter		1
dictionary		2
dimension		1
direction		1
directrix		1
distance	(1)	3
divide		1
division	(1)	1
divisions		1
drafting		1
drawing		2
equation		1
expansion		1
expectation		1
figure	(1)	3
flower		4
from		1
function	(1)	1
geometric		1
geometry	(5)	47
grammar		1
graph	(3)	22
graphics		1
graphs	(1)	1
height		1
hiss		1
history		1
horizontal		2
hospital		1
hyperbola		4
hypothenuse		3
incisor		1
index		1
insect wing	(1)	1
language		1
Latin		3
length	(1)	2
line	(15)	66
lines		3
logarithm		3
logarithms		1
mantissa		3
mathematics	(4)	48
measurement		1
measuring		1
medical		2
medicine		2
molasses		1
monissa		1
name		2
narcissus		3
nature		1
number		2
obssession		2
opening		1
ordinal		1
ordinant		4
ordinate	(31)	182
ordinates	(1)	4
oval	(1)	1
parabola		2
parallel		1
part	(1)	2
perpendicular		1
physics		5
physiology		2
pipsissewa		1
plane		1
plant		1
plasmolysis		1
pleasure		1
plot		4
plotting		2
point		3
points		2
positive		1
proboscis		1
psychology		2
queen		1
scale		1
schism		1
science		3
scientific		1
scissors		5
separation		3
sister		1
S		1
sore		1
space		1
square		1
squares		3
statistics		4
surd		1
tangent		2
technical		1
theorem		2
titrate		1
tooth		1
tracing		1
trans		1
triangle	(4)	29
trigonometry		47
trite		1
under	(1)	1
upright		1
vertical		2
x		1
x axis		2
x + y		1
y axis		1
zenith		1
zero		1

93. GRAVITATION.

Individuality Frequency, 81.

Failure Frequency, 2.

action		1
aerial		1
apparatus		1
apple	(2)	19
astronomy		1
attraction	(6)	34
aviation		1
balance		1
ball	(1)	5
bodies		1
body		1
B.		1
bullet		1
car		1
center	(1)	7
centrifugal		3
centrifuging		1
clinostat		1
C.		1
constant	(1)	4
converging		1
Darwin		1
declivity		1
descent		1
down	(1)	9
downward		4
draw		1
drawing		2
drop		5
dropping		1
dyne		1
earth	(15)	107
equator		1
erg		1
exhortation		1
experiment		1
fall	(4)	39
falling	(6)	46
falling body		1
feather		1
force	(7)	146
formula		1
fraction		1
g.	(2)	2
generalization		1
geography		2
globe	(2)	2
grave		2
gravid	(1)	1
gravimetric		3
gravitate	(1)	2
gravity	(1)	30
gravy		1
ground		1
heavy		8
height		1
hill		1
Holt's Ledge		1
hope		1
hydrometer		1
inertia		1
insoluble		1
(Sir) Isaac		1
(Sir) Isaac Newton		1
law	(4)	42
laws		2
levitation		2
magnet		1
magnetism		2
mass	(4)	6
matter		1
mercury		1
method		1
molecular	(1)	1
molecule		1
momemtum		1
motion		1
move		1
nature		1
N.		1
Newton	(18)	187
pedestal	(1)	1
physical		2
physics	(6)	66
physics experiment		1
pole		2
power		5
process		1
pull	(3)	21
pulling		2
repulsion		1
resistance		1
rolling		1
root		1
scale		1
science		2
scientific		1
secret		1
separation		1
settling		1
sex		1
solids		1
specific		2
speed		1
square	(1)	1
stone	(1)	6
subtraction		1
sun	(1)	3
swing		1
system		1
theory	(2)	12
32.2		1
tire		1
tumble		1
unfailing		1
unit		2
units		1
velocity		1
volume		1
water		2
weighing		1
weight	(7)	68
world		1

94. GALVANIC.

Individuality Frequency, 58.

Failure Frequency, 6.

action	(3)	14
apparatus		1
attraction		2
bath tub		1
batteries	(1)	1
battery	(28)	253
bottle		1
bright		1
burn		1
cell	(7)	56
cells	(1)	1
chemistry		9
coil	(1)	1
copper		2
current	(11)	75
currents		2
d'Arsonval		1
discharge		1
dynamic		3
electric	(6)	46
electrical		4
electrical cell	(1)	1
electricity	(24)	179
energy		3
equator		1
experiment	(1)	1
explosive		1
Faraday		2
faradic	(3)	7
force	(1)	53
French		1
frog	(3)	12
frogs		3
Galileo	(1)	1
Galton		1
Galva		2
Galvan		1
Galvani	(1)	9
galvanize		10
galvanized		2
galvanometer		10
galvanoscope		3
Galveston		6
G.		2
great force		1
hard		2
heat		1
instrument		3
iron		36
Italy		2
jar		1
jerk		1
jump		1
laboratory	(1)	1
law		2
life		1
lining		1
live		1
machine		2
machinery		2
magnet		2
magnetic		2
magnetism		1
man	(1)	2
mechanics		2
mercury		1
metabolism		1
metal		5
metallic		1
metals		1
meter		3
motor		1
needle		2
physics		28
power		10
press		1
pressure		9
process		2
psychology		1
psychometer		1
rapid		1
reaction		1
reactions		1
reflex		2
roof		1
schoolroom		1
science		1
shock	(2)	9
sinusoidal		1
soap		1
static		3
steel		1
stimulation		3
storm		1
strong		4
structure		1
tank		2
Texas		1
theory		5
thermometer		1
tin		7
Titanic		1
tub		1
tube		1
twitch		1
vanguard		1
vats		1
vessel		1
volcano		2
volt		2
Volta	(2)	4
voltaic	(1)	4
voltmeter		1
wire		1
zinc		4

95. LOGARITHM.

Individuality Frequency, 92.

Failure Frequency, 1.

abscissa		1
algebra	(3)	47
analysis	(1)	1
analytics		1
anti-logarithm	(1)	2
arithmetic		34
base		3
bird		1
blackboard		2
black book		1
book	(5)	53
books		1
B.	(1)	2
C.		1
calculate		1
calculation		7
calculus		4
catalogue		1
C.	(1)	1
chemistry		1
coefficient		1
college		1
cologarithm		2
column		2
common		1
complicated		1
computation	(3)	7
correlation		1
cosine	(1)	2
curve		2
decimal	(1)	8
decimals		1
deduction		1
differentiation		1
difficult		2
difficulty		1
divide		1
D.		1
e.		1
easy		1
element		1
engineering		1
Euclid		1
examination		1
exponent	(1)	12
exponential		1
F.		1
figure		3
figures	(3)	24
formula		1
function	(1)	1
geodesy		1
geometry	(1)	36
great		1
hard		2
hardships		1
hate		1
higher mathematics		1
Holman's tables		1
index	(1)	2
infinity		1
Japanese		1
J.		2
K.		1
labyrinth		1
Latin		1
L.		1
L.		1
lobster		1
log		2
logarithm table		1
log-chain		1
logic		1
longitude		1
L.		1
mantissa		3
manual		1
M.		1
mathematics	(11)	115
misery		1
multiplication		5
Napier	(8)	26
Naperian		2
natural		1
nine		1
number	(10)	56
numbers	(3)	26
page		1
part		2
per cent		1
physics		1
P.		2
P.		1
plane		1
power	(4)	8
powers		1
principle		1
problem	(1)	5
problems		1
progression		1
proof		1
reciprocal		1
root	(1)	1
rotten		1
row of figures		1
rule		2
school		1
science		2
sea	(1)	1
secant		1
series		1
sine	(2)	5
slide rule		2
S.		1
solution		1
speed		1
square		2
study		2
sum		1
surveying		2
symbol	(1)	1
system		1
table	(16)	18
tables	(2)	38
tangle		1
ten	(1)	2
theorem		1
theory		1
together		1
transcendental		1
triangle		1
trigonometry	(15)	223
trouble		1
useless		1
Weber's law		1
window seat		1

96. CALYX.

Individuality Frequency, 70.

Failure Frequency, (2) 41.

alchemist		1
anatomy		1
animal		2
apples		1
beautiful		1
Bible		1
biology		2
book		1
botanical	(1)	2
botany	(5)	75
bud		1
Calais		1
Calef		1
Caliph		1
Calixtus		1
Calox	(1)	9
catastrophe		1
C.		1
Celtic		1
chalice		3
chemistry		1
circle		2
color		1
corolla	(22)	132
corona		3
cuneiform		1
crystal		1
cup	(1)	12
curve		2
drill		1
eat		1
electricity		1
flower	(41)	464
flowers	(2)	19
fruit	(1)	1
geology		1
geometry		2
grand		1
Greek		2
green		6
heat		2
helix		2
history		1
index		2
K.		1
K.		1
K.	(1)	1
kidney		2
larynx		1
leaf		1
lily		9
lime	(1)	1
lotus		1
morning glory		1
morphology		1
mould		1
myths		1
name		1
nasturtium		1
nature		1
odor		1
onyx	(1)	1
orchid		1
outer		1
part		1
passion flower		1
perianth	(1)	2
petal	(3)	19
petals	(1)	2
physiology		1
pink		1
pistil		6
plant	(9)	59
plants		7
point		2
pollen		5
powder		1
quandary		1
rananculus		1
root		1
rose		1
salt		1
science		1
seed	(1)	1
sepal	(2)	8
sepals	(1)	3
shape		1
shell		1
skeleton		1
skin		1
spiral		1
stalk		1
stamen	(1)	8
stamens	(1)	1
stem	(1)	8
stone		1
substance		1
tapeworm		1
tooth		2
top		1
triangle		1
unknown		1
vacate		1
violet		2
waxen		1
wound		1
yellow		1

97. POLARIZATION.

Individuality Frequency, 132.

Failure Frequency, 6.

acids		1
angle		1
apparatus	(1)	2
arctic		1
arrangement	(1)	1
arranging		1
arrow		1
asters		1
astronomy		3
atoms		2
attraction		8
axis		1
battery	(2)	31
bear	(1)	3
biology		1
bodies		1
body		2
botany		1
bubbles		1
carbon		1
cell	(2)	30
cells	(2)	3
center		3
centralization		3
changing		1
chemical		1
chemistry	(1)	12
chromosomes		1
cockroach		1
cold		4
compass		3
converging		1
C.		2
copper		1
crater		1

crosses		1
crystal	(1)	3
crystallization	(1)	3
current	(2)	9
currents		1
cytology		1
depolarization		1
dextrous		1
direction	(1)	3
division		1
earth		3
egg		4
electric		5
electrical	(1)	3
electricity	(2)	130
electrode		2
electrodes		1
electrolysis		2
electro-magnet		1
end		3
ends	(1)	2
energy		1
engine		1
eugenics		1
examination		1
expedite		1
experiment		1
explorer		1
eyes		1
fat	(1)	1
fertile		1
fertilization		5
filings		1
flower		10
flowers		2
focussing		1
force		2
formaldehyde		1
freeze		1
freezing		1
frigid		1
G.		1
geography		2
glass	(1)	1
globe		1
golf		1
grace		1
harmonization		1
heat		2
heavens		1
heredity		1
hospital		1
hydrogen		3
ice		1
instrument	(2)	4
ionization		2
iron		1
isomerism		1
laboratory		1
law		1
lens		1
leptolene		1
light	(52)	320
lily		1
lines		1
liver		1
magnet	(2)	27
magnetic		3
magnetism	(1)	26
magnetization		1
magnets		1
maturation		1
mercury		1
metal		1
microscope	(1)	6
mineralogy		1
mitosis		2
motion		2
movement		2
moving		1
navigation		1
needle		2
needless		1
negative	(1)	2
neutralization		1
Nicol		1
nitrate		1
non-polarizable		1
north		3
North Pole		1
optics		2
Peary		3
perplexity		1
phenomenon	(1)	1
philosophy		1
physical chem.	(1)	1
physics	(4)	67
physiology		1
pistil		1
plant		2
plants		1
Polack		1
Poland		1
polar	(3)	5
polar bear		1
polarimetric		1
polariscope	(1)	6
polarity		1
polarized		1
pole		16
poles		7
pollen		3
porous		1
position		2
powder		1
pressure		1
prism		4
process		1
psychology		1
Ramon y Cajal	(1)	1
red		1
refraction		1
repetition		1
reproduction		1
retina		1
rhomboidal	(1)	1
science		6
sea		1
separation		1
Shackelton		1
spar		1
spectroscope		1
spectrum		1
spindle		1
stamen	(1)	1
star		2
starch	(1)	1
Steffanson		1
stick		1
storage		1
sugar	(4)	27
sugars	(1)	2
sun		1
tartaric		1
telescope	(1)	1
theory		1
together		1
trigonometry		1
tube		1
turn		1
turning		1
watch		1
water		1
weakening		1
whiteness		1
wind		1
yellow		1
Z.		1

98. CEPHALIC.

Individuality Frequency, 120.

Failure Frequency, (5) 42.

acid		3
action		2
adjective		2
anatomy		1
ancient		1
androcephalic		1
angel		1
angelic	(1)	2
animal		2
anterior		1
anthropology		4
ascetic		1
baby		1
back		1
belly		1
biology	(1)	4
blind		1
body		2
bone	(1)	3
bones		1
botany	(1)	3
brachy-		1
brachycephalic		4
brain	(18)	112
brainy	(1)	1
bucephalus		1
caliph	(1)	2
ceiling		1
centaur		1
centipede		1
central		3
centripetal		1
cephalopod	(1)	5
cephalothorax		2
cephalus		9
cerebrum		1
cervical	(1)	1
Charybdis		1
chemistry		1
child		2
compression		1
cranium		1
degenerate		1
dictionary		4
difficult		1
diffuse		1
disease		19
division		1
dog		1
dolicho-		2
dorsal	(1)	2
dorso-		1
elephantine		1
elephants		1
embryo		1
embryology		1
embryonic	(1)	1
encephalon		1
end	(1)	3
endocephalic		1
ethnological		1
eugenics	(1)	1
eyes		1
fallacy		1
fallible		1
feet		1
finger		1
flexure		1
force		1
forehead		1
form		1
ganglion		2
general		1
geology		1
ghosts		1
giant		1
gland		4
gonorrheal		1
good		1
Greek		1
groove		1
growth		1
haziness		1
head	(34)	287
heads		1
headwards	(1)	1
heaven		1
horse		3
hospital		1
hydro-		1
hydrocarbon		1
hydrocephalic		9
hydrocephalus		2
idiot	(1)	1
ignorance		1
index	(23)	140
jaw		1
large		1
lobe		3
lobster		2
man		2
meaning		1
measurement		1
median		1
medical	(1)	3
medicine		3
medium		1
medullar		1
membrane		6
mesocephalic		1
microcephalic		1
mind		1
neck		1
nerve	(1)	2
nerves		1
neurology	(1)	1
nomenclature		1
obstetrics		1
occipital		1
person		1
petal		2
phalanx		1
phallic		1
physics		3
physiology		9
plant		1
podalic		1
portion		2
prognathous		1
prophylactic		2
psychology		3
region	(1)	3
round		2
sage		1
Sapphic	(1)	1
science		9
scientific		2
sepal		2
sepulchral		1
seraph		1
seraphic		2
seven		1
Sisyphus		1
skin		1
skull		12
sleep		1
slink		1
sociology		1
sour		1
sphinx		1
spinal		1
spirits		1
squid		1
stone		1
suffice		1
sufficient		1
suffix		1
suture		1
sylph		1
sympathetic		1
symphony		1
synthetic		1
syphilis		10
syphilitic		2
syphilization		1
syphon		1
terrible		1
thorax		3
thought		1
ulcer		1
vein		3
Wassermann		1
white		1
woods		1
zoology	(1)	3

99. PROTEID.

Individuality Frequency, 86.

Failure Frequency, 9.

albumen (3) 30
amino-acid 5
amino-acids 1
ammonia 1
amoeba 1
ancient 1
animal 3
animalcule 1
animals 1
A. 1
backbone 1
bacteriology 1
bean 3
beans (1) 6
beef extract 1
beginning 1
biochemistry (1) 1
biology 6
birds 1
blood 1
body 3
botany 4
bread (1) 3
but 1
carbohydrate (1) 41
carbohydrates 2
carbon 4
casein (1) 1
cell (1) 3
cheese 3
chemical 1
chemistry (9) 41
C, O, H, N (1) 1
colloid 2
commission 1
complex 1
compound (1) 6
cookery 1
cooking (1) 1
corn 2
diet 6
dietetics 2
digestion 2
dinner 1
early 1
eat 3
eats 1
economics 1
egg (4) 18
egg albumen (1) 1
eggs 2
egg white 1
Endymion 1
evolution 1
fat 24
fats 3
first 2
F. (1) 2
flesh 1
flour 1
F. (1) 1
food (32) 422
foods 5
food stuff 1
form 1
formula 1
fried egg 1
gland 1
glutton 1
grain 2
granule (1) 1
gravy 1
Greek 1
grub 1
health 1
hybrid 2
hydrocarbon (1) 3
hygiene 3
jelly 1
J. 1
life (2) 7
M. 1
many (1) 1
material 1
matter (1) 4
meal 1
meat (4) 53
M. 1
menu 1
metabolism (1) 6
milk (1) 7
molecule (1) 5
multiform 1
muscle 2
mythology 2
Nereid 1
nitrogen (9) 36
nitrogenous 7
nourishment 3
nucleus 1
nutrient 1
nutriment 1
nutrition 8
ocean 1
organic 1
organic chemistry 2
organism 1
peptone 1
physics 1
physiology (1) 8
polotin 1
polypeptids 1
post 1
potato 2
potatoes 3
powder (1) 3
predigested 1
primitive 1
protein (1) 14
proteus 1
protest 1
protoplasm (6) 18
protos 1
protozoa (1) 5
protozoon 1
purification 1
ration 1
reaction (1) 1
salt 1
sea 1
serum 1
small 1
starch (2) 10
stiff (1) 1
stomach 1
strength 3
stuff (1) 1
substance (3) 16
sugar 4
T. 1
thickness 1
tissue 1
vegetable 1
vegetarian 2
vegetarianism 1
wheat 4
word 1
zoology 2

100. KINETIC.

Individuality Frequency, 58.

Failure Frequency, 12.

acting 1
action 6
active 5
activity (1) 2
association 1
attraction 1
available 1
Canada 1
change 1
changing 2
chemistry (1) 4
cinematograph 1
close 1
color 2
Connecticut 6
C. 1
doctor 1
dynamic 5
dynamics 1
dynamo 1
electrical 1
electricity 7
electrons 1
energetic (1) 1
energy (43) 410
equivalent 1
fall 1
feeling 1
force (13) 145
forceful 1
function 1
gas (1) 3
gases 1
genesis 1
Giddings 1
glass 1
heat (1) 12
hypothesis 2
inertia 1
interesting 1
kaleidoscope 1
kaleidoscopic 1
karyokinesis 1
kidney 1
kimono 1
kindred 1
kinesis 1
kinesthesis 2
kinesthetic 7
kinetoscope 3
latency 1
latent 2
light 3
lively 2
machine 1
mass (1) 1
mechanic (1) 1
mechanics (1) 6
molecular 4
molecule 1
molecules 1
motion (11) 60
move 1
movement (3) 21
movie 1
moving (1) 8
muscle 5
muscles 1
muscular 1
$\frac{1}{2} m v^2$ 2
phonetic 2
physical 2
physics (5) 46
potential (2) 26
power 27
powerful 1
pressure 1
principle 1
protoplasm 1
psychology 4
quick 3
reaction 2
relationship 1
rest 1
science 2
sensation 3
skin 1
sound 1
static (2) 15
steam 1
strength 1
sun (1) 2
swift 2
sympathetic 1
technical 2
theorem 1
theory (11) 56
tongue 1
vigor 1
writing 1

APPENDIX TO THE FREQUENCY TABLES.

1. *Geography*:

Any term or name in physical geography.
Any political division in geography.
Any noted geographical explorer or writer.

2. *Participle*:

Any term of grammar or syntax.
Any language.
Any participle.

3. *Waterloo*:

Any city in Belgium.
Any noted military or naval commander in the European armies involved in the Napoleonic campaigns.
The name or location of any historically important engagement in the world's wars.

4. *Refraction*:

Any refracting medium.
Ocular errors of refraction.
Any optical instrument.
Any term of optics.

5. *Arithmetic*:

Any term of arithmetic or algebra.
Any number.
Any writing implement or computing device.

6. *Botany*:

Any botanical term or name.
Any instrument employed in experimental or other work in botany.
Any term of agriculture.

7. *Isomerism*:

Any term of organic chemistry.
Methods or devices for distinguishing isomers.
Any substance of a group of isomers or polymers.

8. *Portugal*:

Any term or name in physical geography.
Any political division in geography.

9. *Amoeba*:

Any term in biology.

10. *Declension*:

Any term of grammar or syntax.

Any English or foreign word commonly used as an example in the study of declensions.

Any word pertaining to the study of language.

11. *Burette.*

Any word pertaining to technique or apparatus of chemical analysis.

Any substance that is more or less frequently subjected to or used in volumetric chemical analysis.

12. *Physics*:

Any term of mathematics or physics.

Any method or apparatus of the physical laboratory.

Any term of applied physics.

13. *Hyperbole*:

Any term of grammar, syntax, or rhetoric.

Word denoting, or pertaining to, emotional element of expression, or accuracy in expression.

Any term of mathematics.

14. *Retina*:

Any term of nervous anatomy or physiology.

Any term of anatomy, physiology, or pathology of the visual apparatus.

Any term of optics.

15. *Coagulation*:

Any word denoting or implying a transition from a liquid to a solid state or from one of loose to one of more compact aggregation.

Any substance that is commonly subject to such a transition.

Any process, mechanism, or agency that may produce or hinder coagulation.

Any component of blood, egg, milk, muscle or other typically coagulable material.

16. *Cervantes*:

Any word denoting high intellectual distinction.

Any word pertaining to literature or rhetoric.

Any character, custom, sentiment, or principle prominently dealt with in Cervantes' Don Quixote.

17. *Franchise*:

Any term of civics or political economy.

Any general or special designation of an enterprise commonly requiring a government franchise for its organization or maintenance.

Any political division of a country or a state.
Any population group of a country or a state.
Any word denoting or implying distinction of class or caste.

18. *Subtraction*:

Any term of arithmetic or algebra.
Any number.
Any writing implement or computing device.

19. *Metabolism*:

Any food substance.
Term pertaining to ingestion, digestion, absorption or assimilation of food or to nutrition in any way.
Term pertaining to destructive tissue changes and excretion.
Any organ, system, tissue or fluid of the animal body.
Any vital function.
Any medicament, poison, or disease markedly affecting metabolism.
Any term denoting change or a process of change.
Any hygienic condition or principle affecting metabolism.

20. *Predicate*:

Any term of grammar or syntax.
Name of any language.

21. *Mollusc*:

Any term of zoology.
Any water animal.
Any body of water or term denoting land connected therewith.

22. *Inquisition*:

Word denoting any form of torture or capital execution.
Word denoting or implying mediaeval times or institutions.
Word denoting any judicial authority or procedure.
Any ecclesiastic term.
Any word denoting or implying oppression, derogatory qualification or resentment.

23. *Amphibious*:

Any term of zoology.
Any water animal.
Any body of water or term denoting land connected therewith.
Any word pertaining to habits of water life, such as methods of propulsion, etc.

24. *Decimal*:

Any term of arithmetic or algebra.
Any number.
Any writing implement or computing device.
Any term pertaining to currency.

25. *Hydraulic*:

Any water-way or hydraulic apparatus.

Any word denoting or implying energy; any apparatus for the production, measurement, transmutation, or transmission of energy.

Any operation of engineering that may be performed with the aid of hydraulic apparatus.

26. *Osmosis*:

Any animal, vegetable, or artificial tissue or apparatus prominently invovled in phenomena or experiments of osmosis.

Any general or special name of a substance noted either for marked diffusibility or for indiffusibility through semi-permeable membranes.

Any biological function prominently dependent on the phenomenon of osmosis.

Word denoting or implying movement of a fluid substance or permeability of a solid substance.

27. *Percentage*:

Any term of arithmetic or algebra.

Any number.

Any writing implement or computing device.

Any word pertaining to currency, banking, or commerce.

Any term of scientific or applied statistics.

28. *Cerebellum*:

Any part of the nervous system or of the skeleton enclosing it.

Any function of the cerebellum.

Any common symptom of cerebellar disease.

Any pathological process or lesion that may affect the cerebellum.

29. *Fractions*:

Any term of arithmetic or algebra.

Any number.

Any writing implement or computing device.

30. *Titration*:

Any word pertaining to technique or apparatus of chemical analysis.

Any substance that is more or less frequently subjected to or used in volumetric chemical analysis.

Any branch of science or technology in which titration forms a part of the technique.

31. *Carbohydrate*:

Any food substance.

Term pertaining to the ingestion, digestion, absorption, or assimilation of food or to nutrition in any way.

Term pertaining to technique, apparatus, or reagents of food analysis.

Any organ, system, tissue or fluid of the animal body.

32. *Duodenum*:

Any food substance.

Term pertaining to the ingestion, digestion, absorption, or assimilation of food.

Any organ, fluid, or function of the digestive system.

Any pathological lesion or process that may affect the digestive system; any symptom of such a lesion or process.

Any medicament or therapeutic procedure commonly employed in the treatment of disorders of the digestive system.

33. *Cosecant*:

Any term of geometry or trigonometry.

34. *Biology*.

Any term of biology.

The name of any institution of learning.

Any animal or plant.

35. *Odyssey*:

Any character in the Homeric poems.

Any term of literature.

The name of any writer or locality of ancient Greece or Rome that is of historical importance.

36. *Vertebrate*:

Any term of zoology.

Any animal.

Any term pertaining to the vertebrate skeleton.

Any division of the body characteristic of a vertebrate organism.

37. *Gravimetric*:

Term pertaining to technique or apparatus of chemical analysis.

Any substance that is more or less frequently subjected to or used in gravimetric chemical analysis.

Any unit or system of weight measure.

38. *Federal*:

Any high office or department of the federal government.

Any country.

Any word denoting federation or union.

The name of a president of the United States.

Any organization of whose charter or corporation name the word "federal" forms a part.

39. *Morphology*:

Any word denoting or implying a pathological condition.

Any term of biology, anatomy, or physiology.

Any term of anatomic technique or apparatus.

40. *Hypothenuse*:

Any term of geometry or trigonometry.

41. *Magellan*:

Any country, continent, or ocean.
Any term of navigation or of geography.
Any geographical explorer of historical importance.

42. *Hexameter*:

Any term of rhetoric.
Any noted poet or poem.

43. *Meteor*:

Any term of astronomy.
Any word descriptive of a meteor, its composition, movements or effects.

44. *Momentum*:

Any word denoting or implying an act or means of motion or of sudden arrest of motion.

45. *Cornwallis*:

Any military term or term of warfare.
Any word referring to a scene or incident of the prominent campaigns in the American revolution.
The name of any personage of historical importance connected with the latter colonial times, the revolution, and the early years of the Union.

46. *Protozoon*:

Any term in biology.
Any disease produced by a protozoon.

47. *Syntax*:

Any term of grammar or syntax.
Word pertaining to the study of language.
Any language.

48. *Distillation*:

Any operation or phenomenon of which distillation forms a part or which forms a part of distillation.
Any apparatus which is used in distillation.
Any substance which is more or less commonly subjected to distillation or manufactured with the aid of distillation.
Any chemical or technological operation which may be employed, like distillation, for the purification or separation of substances.

49. *Pollen*:

Any term of botany.
Any agency that commonly serves for transference or dissemination of pollen or seeds.
Any term pertaining to reproduction of biologic organisms.

50. *Peninsula*:

Any term or name in physical geography.
Any political division in geography.

51. *Binomial*:

Any term of mathematics.

52. *Crustacean*:

Any term of zoology.
Any water animal.
Any body of water or term denoting land connected therewith.

53. *Bonaparte*:

Any military term or term of warfare.
Any noted military or naval commander in the European armies involved in the Napoleonic campaigns.
Any word referring to a scene or incident or the prominent features of the Napoleonic campaigns.
Word expressing or implying esteem or commendation of any kind, or lack of it.

54. *Meridian*:

Any geometric, trigonometric, or astronomic term more or less frequently employed in geography.
Any country, prominent city, or term in physical geography.
Any term of navigation.
Any apparatus of navigation or astronomy.
Any division of the diurnal cycle.

55. *Chlorophyll*:

Any plant, part of a plant, or plant constituent.
Any term of botany.

56. *Tetrahedron*:

Any term of geometry.
Any substance commonly met with in crystalline form.

57. *Madagascar*:

Any term or name in physical geography.
Any political division in geography.
Any tropical animal, plant, or commercial product.
Any term of anthropology.

58. *Corolla*:

Any flower or part of one.
Any flowering plant.
Any color.

59. *Ventral*:

Any organ or region of the animal body.
Any animal.
Any term of anatomy.

60. *Belgium*:

Word obviously referring or pertaining to the war of 1914-1919.
Any European country.
Any Belgian colony.
Any city in Belgium.
Any personage prominently connected with Belgian history, science, literature, or art.

61. *Tangent*:

Any term of geometry or trigonometry.
Word denoting or implying contact or proximity.
Word denoting or implying an act or means of rapid motion.

62. *Dorsal*:

Any organ or region of the animal body.
Any animal.
Any term of anatomy.

63. *Colloid*:

Any colloid substance.
Word denoting or implying a transition from a liquid to a solid state or from one of loose to one of more compact aggregation.
Any animal, vegetable, or artificial tissue or apparatus prominently involved
Any substance that is commonly subject to such a transition.
in experiments of osmosis.

64. *Equator*:

Any geometric, trigonometric, or astronomic term more or less frequently employed in geography.
Any term of physical geography or meteorology.
Any country or prominent city situated within or near the tropics.
Any tropical animal, plant, or commercial product.
Any term of anthropology.
Any term of navigation.
Any apparatus of navigation or astronomy.

65. *Judiciary.*

Any term of law, civics, or penology.
Any political division of a country or a state.
The name of any prominent judge.

66. *Synthesis*:

Any product of synthetic chemistry.
Word denoting or implying a transition from a lower to a higher degree of complexity.

67. *Athens*:

Any word pertaining to the history, art, philosophy, or science of ancient Greece.
Any noted city of ancient Greece, Rome, Egypt, or Judea.
Any personage of importance in the history of ancient or modern Greece.
Any character in Greek mythology.

68. *Epithelium*:

Any organ, region, or tissue of an animal or plant.
Any characteristic anatomical or chemical constituent of epithelial organs.
Any variety of epithelium or epithelial cells.
Any term of anatomy.
Any animal or plant.
Any secretion or excretion.
Any lesion of skin or mucous membrane.

69. *Feudalism*:

Any term of civics or political economy.
Any word denoting or implying distinction of class or caste.
Word denoting or pertaining to mediaeval times, historical incidents, or institutions.
Any word denoting or implying oppression, derogatory qualification, or resentment.
The name of any personage or place of historical importance connected with mediaeval times.
Any military term or term of warfare.

70. *Coefficient*:

Any algebraic symbol.
Any natural phenomenon the law of which is more or less commonly expressed by a mathematical formula.
Any term of mathematics.
Any number.
Word in any way pertaining to scientific or applied statistics.

71. *Perennial*:

Any word involving the concept of time.
Any term of botany.

72. *Plebeian*:

Any term of civics or political economy.
Word denoting or implying distinction of class or caste.
Word denoting or pertaining to the times, historical incidents, or institutions of ancient Rome or Greece.
Word denoting or implying oppression, derogatory qualification, or resentment.
The name of any personage or place of historical importance in connection with ancient Rome or Greece.
Any military term or term of warfare.

73. *Catalytic*:

Word denoting or implying chemical activity or an act or means of initiating or hastening chemical activity.
Any term of chemistry.

74. *Embryo*:

Any word denoting or implying age.
Any term of biology.
Any animal or plant.

75. *Spectrum*:

Any term of optics.
Any apparatus or reagent used in spectrum experiments.
Any color.

76. *Continent*:

Any term or name in physical geography.
Any country.
Any noted geographical explorer or writer.

77. *Spore*:

Any term in biology.
Apparatus, technique, or material of any branch of experimental biology.
Word denoting or implying size, appearance, or consistency.
Any spore bearing animal, plant, or bacterium.

78. *Theorem*:

Any term of geometry or trigonometry.

79. *Himalaya*:

Any term or name in physical geography.
Any country.
Word denoting or implying elevation, means of elevation, or process of elevation.
Any animal or plant.

80. *Renaissance*:

Word denoting or implying mediaeval times or institutions.
Any word denoting liberation, emancipation, enlightenment, or approving qualification.
Word denoting or implying the spirit of progress as contrasted with that of conservatism.
Any European nationality, country, or important city.
Any branch of literature, art, science, or civic or economic activity.
Any personage of historical importance from the times of early Italian Renaissance to those of the French revolution.
Any social institution markedly affected by the Renaissance.
Any product of handicrafts inspired by the styles of the Renaissance.

81. *Quotient*:

Any term of arithmetic or algebra.
Any number.
Any writing implement or computing device.

82. *Oxidation*:

Any term of chemistry.
Any result or manifestation of oxidation.
Any substance commonly subject to oxidation.
Any vital process involving oxidation.
Any agency, apparatus, or technique employed in experiments of oxidation.
Any branch of science or technology in which the process of oxidation plays an important part.

83. *Haemoglobin*:

Any term of animal anatomy, physiology, or pathology.
Term of pathologic technique or of therapeutics used in connection with the investigation and treatment of abnormal conditions of the blood.

84. *Axiom*:

Any term of metaphysical dialectics.
Word denoting or implying belief or feeling of certainty or conviction.
Any term of geometry.

85. *Amazon*:

Any term or name in physical geography.
Any term or name of classical mythology.
Word denoting or implying the female sex.
Word denoting or implying strength or aggressiveness.

86. *Isosceles*:

Any term of geometry.

87. *Cohesion*:

Any physical property of matter.
Any adhesive medium, substance, or contrivance.
Any material especially noted for its cohesion.
Word denoting or implying a state of aggregation of matter or resistance to disaggregation.

88. *Protoplasm*:

Any term of biology.
Word pertaining to the structure, composition, or properties of protoplasm.
Word pertaining to apparatus, technique, or reagents of biological investigation.

89. *Centrifugal*:

Any term of dynamics or celestial mechanics.

Any contrivance involving rotary motion.
Any apparatus, substance, or technique of investigation or manufacture involving the use of centrifugal force.
Word denoting or implying rapid motion.

90. *Molecule*:

Any term of chemistry.
Any chemical substance.

91. *Cotyledon*:

Any term of botany.
Any plant.

92. *Abscissa*:

Any term of geometry or trigonometry.
Word pertaining to the diagrammatic representation of statistical measurements.

93. *Gravitation*:

Any term of celestial mechanics, aeronautics, or ballistics, or pertaining to theory of motion.
Any means of measuring weight or of utilizing the force of gravitation.
Any measure of weight.
Word denoting or implying weight.
Any substance or object especially noted either for lightness or for heaviness.

94. *Galvanic*:

Any term of electricity.
Any apparatus, technique, or reagent employed in electroplating.
Any substance or object commonly subjected to electroplating.
Word pertaining to physiological effects of galvanic electricity.

95. *Logarithm*:

Any term of mathematics.

96. *Calyx*:

Any term of botany.
Any flowering plant.
Any color.

97. *Polarization*:

Any term of optics.
Any apparatus, technique, or substance employed in experiments with polarized light.

98. *Cephalic*:

Any term of anatomy.
Any term of anthropology.

Any animal.
Any term of nervous or mental pathology.

99. *Proteid*:

Any food substance.
Term pertaining to the ingestion, digestion, absorption, or assimilation of food or to nutrition in any way.
Term pertaining to technique, apparatus, or reagents of food analysis.
Any organ, system, tissue, or fluid of the animal body.
Any chemical substance which enters into the constitution, or which may be produced as a decomposition product, of proteids.

100. *Kinetic*:

Any term of physics.
Any source or manifestation of energy.

PART II. NORMS REPRESENTING VARIOUS DEGREES OF EDUCATION.

The results of our test have varied greatly in different subjects, depending probably on many factors; among these education occupies, of course, a position of importance.

For the purpose of measuring the influence of education we collected three hundred test records from subjects selected as follows: twenty-five pupils from each, the fifth, sixth, seventh, and eighth elementary school years; the same number from each of the four high school years; and the same from each of the four collegiate years.

This material was collected in the fall of 1915, shortly after the beginning of the school year, the work in the elementary school being done between November 22 and December 15; that in the high school between October 4 and 20; and that in college between October 25 and November 15.

In Table 2 we give the calculated averages for all the groups distinguished according to school grade, together with the average deviation for each group.

It appears in the table that education up to the first collegiate year, but not beyond, influences the results of the test. The differences presented by the groups below those of college students are, however, not entirely to be attributed to the influence of education; for an examination of this and other material in our possession shows that at least two other factors contribute toward the results shown in the table: native mental capacity and physiological maturation.

Very marked individual differences are to be observed in all groups; this is shown by the average deviations given in the table for each group and even more strikingly, of course, by the contrasts between the highest and lowest scored test records in each group. Thus, for example, the extremes of high standard value for the fifth elementary school year group were 6 and 251; for

TABLE 2.

			Common reactions.	Doubtful reactions.	Individual reactions.	Failures of reaction.	High standard value.	Individuality index.	Failure index.
Elementary school years.	5th	Average	24.2	2.3	34.0	39.5	117.8	0.384	1.474
		A. D.	8.0	1.6	19.8	27.8	55.0	0.215	0.864
	6th	Average	22.1	1.8	17.4	58.6	143.1	0.202	2.108
		A. D.	7.0	1.5	10.2	17.1	37.0	0.112	0.582
	7th	Average	29.8	2.2	29.0	40.1	175.0	0.314	1.313
		A. D.	7.8	1.7	14.4	19.2	73.7	0.153	0.587
	8th	Average	37.8	1.4	21.9	38.8	338.2	0.239	1.129
		A. D.	7.2	1.2	14.0	19.3	87.2	0.154	0.537
High school years.	1st	Average	50.3	1.9	19.6	28.2	471.6	0.219	0.673
		A. D.	9.0	0.9	8.3	12.2	134.7	0.907	0.381
	2nd	Average	67.8	1.8	15.1	15.4	663.4	0.160	0.283
		A. D.	7.9	1.2	6.5	10.0	109.3	0.068	0.212
	3rd	Average	74.4	1.6	10.7	13.3	795.8	0.110	0.211
		A. D.	5.5	1.0	6.3	8.2	179.2	0.064	0.146
	4th	Average	79.1	1.6	8.2	11.1	956.1	0.084	0.152
		A. D.	6.9	1.2	3.2	7.5	202.2	0.033	0.116
Collegiate years.	1st	Average	82.7	1.3	5.3	10.7	1231.6	0.051	0.132
		A. D.	5.8	0.8	3.0	6.0	242.8	0.032	0.089
	2nd	Average	84.7	1.3	8.0	6.0	1221.6	0.084	0.063
		A. D.	5.4	0.9	3.8	3.9	231.2	0.040	0.044
	3rd	Average	83.8	1.0	8.7	6.1	1270.0	0.091	0.072
		A. D.	7.6	1.0	5.0	4.4	293.3	0.055	0.064
	4th	Average	85.3	1.8	9.1	3.7	1223.4	0.093	0.034
		A. D.	5.8	1.2	4.6	2.8	247.5	0.050	0.028

the 1st high school year group 33 and 746; and for the first collegiate year group 716 and 1553.

The groups being small it is not improbable that the differences between them are partly to be attributed to accidental variations in their composition, although there is as much chance of this factor (in so far as it operates independently of selection) working against as with the factor of education in the general showing.

The influence of selection will be considered in detail in Part III. Suffice it to say here that in a general way it is probably more or less active at the transitions between all education groups represented in the table, and at two points particularly so, namely, at the transitions from elementary school to high school and from high school to college.

Selection here implies the existence of differences in native mental capacity such as are recognized by every teacher. We have secured teachers' estimates of the mental capacities of all the pupils in the elementary schools, high schools, and college, to whom the test had been given. These estimates are expressed in the following terms: *very bright, bright, average, dull, very dull.* For each test record from a subject rated as "very bright" we selected for comparison one from a subject in the same class at school or college rated as "very dull," "dull," or "average," the order of preference being as given here. In some classes, due perhaps to the personal equation of the teachers in the use of the terms proposed by us, more pupils were reported as "very dull" than "very bright." In such instances no test records marked "dull" or "average" were used for the purpose in hand, but the necessary number of those marked "bright" was added to those marked "very bright" to make the total number in that group equal to that in the group marked "very dull."

Table 3 gives the figures for each group in the elementary schools, high schools, and college. These figures show plainly that a correlation exists between the teachers' estimates of mental capacity and the results of the tests.

As to the factor of physiological maturation, it will be recalled that by the Kent-Rosanoff test, the results of which seem to be practically uninfluenced by systematic education, it has been shown to be active only up to the age of eleven years.[1] It would seem that the results of our present test are influenced by the factor of physiological maturation up to the same age, and not beyond it, as may be judged from the figures in Table 4 representing another part of our material. This material consists of one

[1] Isabel R. and A. J. Rosanoff. *A Study of Association in Children.* Psychol. Review, Jan., 1913.

TABLE 3.

Groups of subjects distinguished according to teachers' estimates of mental capacity.		AVERAGES.			
		Common reactions.	High standard values.	Individuality index.	Failure index.
Elementary school groups.	Very bright or bright^{21}	29.5	182.6	0.308	1.424
	Very dull, dull, or average^{21}	27.6	157.0	0.328	1.415
High school groups.	Very bright or bright^{22}	71.0	791.5	0.143	0.207
	Very dull, dull, or average^{22}	67.0	678.6	0.142	0.373
College groups.	Very bright or bright^{13}	88.7	1403.2	0.051	0.049
	Very dull, dull, or average^{18}	84.5	1212.7	0.095	0.051

The small figures in the second column indicate the number of subjects in each group.

hundred twenty-five test records obtained from adult subjects, long out of school, and classified in five groups according to amount of education, compared with data copied from Table 2, i.e., representing subjects who are much younger and still at school but who have had the same amounts of education.

TABLE 4.

		AVERAGES.			
Amounts of education.	Adults, long out of school, or younger subjects, still at school.	Common reactions.	High standard values.	Individuality index.	Failure index.
4 elem. school yrs.	Adult subjects	20.7	158.9	0.223	2.082
	Younger "	24.2	117.8	0.384	1.474
6 elem. school yrs.	Adult "	27.1	240.1	0.209	1.750
	Younger "	29.8	175.0	0.314	1.313
8 elem. school yrs.	Adult "	31.5	258.6	0.253	1.377
	Younger "	50.3	471.6	0.219	0.673
4 high school yrs.	Adult "	73.7	1001.7	0.123	0.361
	Younger "	82.7	1231.6	0.051	0.132
4 college yrs.	Adult "	85.8	1280.1	0.073	0.047
	Younger " *	85.3	1223.4	0.093	0.034

* These subjects are college seniors and not graduates; tests were made at the beginning of the school year.

In this connection it should be borne in mind that not only the factor of physiological maturation but probably other factors as well have had a part in producing the differences between adult and younger subjects shown in the table. Here again the factor of selection, for one, probably plays an important part. For instance, the adults who have had but four or six years of elementary school education must differ considerably, as a group, from school children who have had the same amount of education, but the majority of whom will not drop out of school at this point but will proceed with their studies. Moreover, something is perhaps to be allowed for forgetting in the course of years of being out of contact with school studies.

We find, in fact, that, whether it be due to inferiority by selecor to forgetting, or to other factors, all the adult groups, with the exception of the group of college graduates, show a somewhat lower average of common reactions than the younger subjects of the same amounts of education. Nevertheless the influence of physiological maturation seems to be shown by the high standard values of the groups representing four and six elementary school years of education, but not higher: i.e., the groups which, among school children, include but those who are on the average eleven years of age or less.

In order to eliminate the factors of accidental variation, selection, and, as far as may be possible, physiological maturation, and thus render possible a closer estimate of the influence of the factor of education alone, the test was given a second time during the month of June, 1916, i.e., at the end of the school year, to a number of the subjects in the 8th elementary school year and in the 3rd and 4th high school years.

The results are shown in Table 5. The gains, which, it would seem, are here to be attributed solely, or almost solely, to education, during a period of one school year, amounted to 17.0 per cent in high standard values.

The gains in the course of the corresponding school years shown in Table 2,—to be attributed not solely to education but also to selection and perhaps some other factors as well,—were to the amount of 27.2 per cent.

TABLE 5

		AVERAGES			
Year at school	Tests made at beginning or end of school year	Common reactions	High standard values	Individuality index	Failure index
8th elem. school year 22	At beginning	37.9	342.6	0.244	1.108
	At end	42.9	430.9	0.251	0.890
3rd high school year 20	At beginning	72.9	770.9	0.119	0.224
	At end	78.3	915.9	0.124	0.181
4th high school year 24	At beginning	78.7	932.2	0.085	0.155
	At end	82.1	1045.9	0.075	0.119

The small figures in the first column indicate the number of subjects in each group.

Turning again to the material represented in Table 5, an examination of the test records in individual cases shows here and there a gain in the course of one school year so far beyond the average as to make it doubtful if it could be wholly attributed to the factor of education. Furthermore, in no less than 16 of the 66 cases the tests at the end of the school year showed a loss instead of a gain!—It seems necessary to assume the existence of another factor as influencing the results of our test, a factor which, for want of any knowledge concerning its nature, we have called *temporary condition of the subject.*

We have selected from the three school year groups represented in Table 5, respectively, the cases which showed the highest gains and the highest losses at the end of the school year, and submit here full copies of both the first and the second tests in each case.

In these test records, as in others to be reproduced, the numbers at the left of the reaction words indicate high standard values.

M. P., male, age 12, 8th elementary school year; total high standard values, first test 249, second test 591.

		1st test		2nd test
geography		islands		study
participle	1	phrase	2	speech
Waterloo		island	22	battle
refraction		....		break
arithmetic	1	example	2	study
botany	1	words	3	study
isomerism		....		- -
Portugal		island	6	country
amoeba		....		- -
declension	1	words		pronoun
burette		....		- -
physics		geography	1	study
hyperbole		....	2	speech
retina		....	80	eye
coagulation		....		- -
Cervantes		....		- -
franchise		....		- -
subtraction	19	arithmetic	19	arithmetic
metabolism		....		- -
predicate		word	5	sentence
mollusc		....		- -
inquisition		....		- -
amphibious		....		- -
decimal	38	fraction	38	fraction
hydraulic	13	press	13	press
osmosis		....		- -
percentage		time	15	arithmetic
cerebellum		....		- -
fractions	9	decimal	24	arithmetic
titration		....		- -
carbohydrates		....		- -
duodenum		....		- -
cosecant		....		- -
biology	1	study	1	study
Odyssey		....		- -
vertebrate		....		- -
gravimetric		....		- -
federal		army	33	government
morphology		study		study
hypothenuse		....		- -
Magellan	3	explorer	3	explorer
hexameter		....		- -
meteor	29	star	29	star
momentum		....		- -
Cornwallis	11	general	11	general
protozoon		....		- -
syntax		class	57	grammar
distillation		....		- -
pollen		country	3	bee
peninsula		campaign		campaign
binomial		....		- -

		1st test		2nd test
crustacean		....		- -
Bonaparte		commander	8	general
meridian		....	9	geography
chlorophyll		....		- -
tetrahedron		....		- -
Madagascar	4	country	44	island
corolla		....		- -
ventral		....		- -
Belgium	1	army	9	country
tangent		....		- -
dorsal		....		- -
colloid		....		- -
equator	2	center	2	center
judiciary		department		department
synthesis		....		- -
Athens		nation		country
epithelium		....		- -
feudalism		....		- -
coefficient		....		- -
perennial		....		home
plebian		....		- -
catalytic		....		- -
embryo		....		- -
spectrum		....		- -
continent	6	North America	18	America
spore		....		- -
theorem		....		- -
Himalaya	33	mountain	33	mountain
Renaissance		....		goods
quotient	16	division	3	dividend
oxidation		....		- -
haemoglobin		....		- -
axiom		....		- -
Amazon	54	river	54	river
isosceles		....	81	triangle
cohesion		....		- -
protoplasm		....		- -
centrifugal		....		- -
molecule		science		science
cotyledon		....		- -
abscissa		....		- -
gravitation	7	force		geography
galvanic		....		- -
logarithm		....		- -
calyx		....		- -
polarization		....		- -
cephalic		....		- -
proteid		....		- -
kinetic		....		- -

A. P., female, age 13, 8th elementary school year; total high standard values, first test 345, second test 259.

		1st test		2nd test
geography		subject		study
participle	17	grammar	17	grammar
Waterloo		river		name
refraction		....		- -
arithmetic		subject	2	study
botany		....		- -
isomerism		....		- -
Portgual	6	country	6	country
amoeba		....		- -
declension	19	grammar	19	grammar
burette		....		- -
physics		subject	1	study
hyperbole		....		arithmetic
retina		....		- -
coagulation		....		- -
Cervantes		river	1	name
franchise		....		- -
subtraction	19	arithmetic	19	arithmetic
metabolism		....		- -
predicate	15	grammar	15	grammar
mollusc		....		- -
inquisition		....		- -
amphibious		....		- -
decimal	6	arithmetic	6	arithmetic
hydraulic		....		- -
osmosis		....		- -
percentage	15	arithmetic	15	arithmetic
cerebellum		....		- -
fractions	24	arithmetic	24	arithmetic
titration		....		- -
carbohydrate	9	food		cooking
duodenum		....		- -
cosecant		....		- -
biology		arithmetic	1	study
Odyssey		....		- -
vertebrate		....		- -
gravimetric		....		- -
federal		party		company
morphology		....		- -
hypothenuse		....		arithmetic
Magellan		name		name
hexameter		....		- -
meteor		geography		arithmetic
momentum		....		- -
Cornwallis		name		name
protozoon		....		- -
syntax	57	grammar	57	grammar
distillation		....		- -
pollen		....		- -
peninsula	10	geography	10	geography

		1st test		2nd test
binomial		....		- -
crustacean		flower		flower
Bonaparte		name		name
meridian	9	geography	9	geography
chlorophyll		....		- -
tetrahedron		....		- -
Madagascar		river		- -
corolla		....		- -
ventral		....		- -
Belgium	9	country	9	country
tangent		country		city
dorsal		....		- -
colloid		....		- -
Equator	5	geography	5	geography
judiciary		history		civics
synthesis		....		flower
Athens		people		country
epithelium		....		- -
feudalism		....		- -
coefficient		....		- -
perennial		....		- -
plebeian	11	people		- -
catalytic		....		- -
embryo		....		- -
spectrum		....		- -
continent	3	geography	3	geography
spore		....		- -
theorem		....		- -
Himalaya	33	mountain	33	mountain
Renaissance		....		- -
quotient	7	arithmetic	7	arithmetic
oxidation		....		- -
haemoglobin		....		- -
axiom		....		- -
Amazon	54	river		geography
isosceles		flower		arithmetic
cohesion		....		- -
protoplasm		....		- -
centrifugal		....		- -
molecule		....		- -
cotyledon		....		- -
abscissa		....		- -
gravitation		geography		geography
galvanic		....		- -
logarithm		....		- -
calyx		....		- -
polarization		....		- -
cephalic		....		- -
proteid	32	food		- -
kinetic		Connecticut		- -

S. S., male, age 17, 3rd high school year; total high standard values, first test, 481, second test 1001.

		1st test		2nd test
geography		climate		water
participle	3	infinitive	3	infinitive
Waterloo	21	battle	21	battle
refraction	2	diffraction	35	light
arithmetic		circumference		subtraction
botany	20	plants	8	flowers
isomerism		....	1	isosceles
Portugal	49	Spain	49	Spain
amoeba		caterpillar		worm
declension		case	1	adjective
burette	3	bureau	3	bureau
physics		experiment	36	chemistry
hyperbole		hyperfluous		hyperfluous
retina		revenue	80	eye
coagulation		conjugation		cohesion
Cervantes		servant		survey
franchise		French		France
subtraction	41	addition	41	addition
metabolism		metaphor		mental
predicate	25	verb	1	nominative
mollusc		mollent		molasses
inquisition		acquisition	32	Spain
amphibious	17	water		botany
decimal		cipher	38	fraction
hydraulic		hydrophobia	13	press
osmosis		soaking	2	water
percentage	8	fraction	4	money
cerebellum	16	cerebrum	16	cerebrum
fractions	2	numerator		multiplications
titration		Titus		Titanic
carbohydrate	5	carbon	33	sugar
duodenum		duodecim		unum
cosecant		cozy		consequent
biology	6	animals		monkey
Odyssey	1	Odysseus		English
vertebrate		firm	15	invertebrate
gravimetric	1	gravity	1	gravity
federal	2	union	2	soldiers
morphology		theology		mortal
hypothenuse		arm		arm
Magellan	52	straits	17	strait
hexameter	1	hexagon		dactylic
meteor	1	meter	1	meter
momentum	1	impulse		equal
Cornwallis	4	Washington	25	Yorktown
protozoon		creature	27	amoeba
syntax		meaning	1	word
distillation		sprinkle		germ
pollen	36	flower	36	flower
peninsula	14	land	4	cape
binomial	1	number	7	algebra
crustacean		creeping		flower
Bonaparte	45	Napoleon	45	Napoleon
meridian	9	longitude	6	earth
chlorophyll	5	chloroform		ether
tetrahedron		tetrameter		tetrameter
Madagascar	4	country	1	peninsula
corolla	1	corollary		sickness
ventral	1	ventriloquist	1	ventriloquist
Belgium		ruin	3	Germany
tangent	22	circle	22	circle
dorsal		endorse		Dardanelles
colloid		collie		cholera
equator	1	heat	15	earth
judiciary	1	judicious	1	judicial
synthesis		....		word
Athens	3	Sparta	3	Sparta
epithelium		epigraph		epidemic
feudalism		slave	3	serf
coefficient	7	mathematics	5	algebra
perennial		parenthesis		parenthesis
plebeian	2	aristocracy	23	common
catalytic	1	Catiline	1	Catiline
embryo	1	biology		flower
spectrum		specto		speculate
continent	6	Europe	6	North America
spore		S.		sport
theorem	1	postulate	3	theory
Himalaya		....	33	mountain
Renaissance		rising		uprising
quotient	3	dividend	3	dividend
oxidation		airing	1	air
haemoglobin	1	biology	1	botany
axiom	17	truth	17	truth
Amazon		....	54	river
isosceles	9	equal	81	triangle
cohesion		coincide	27	adhesion
protoplasm		soft	1	body
centrifugal		central		circle
molecule		ridicule	47	atom
cotyledon	8	bean	8	flower
abscissa		absent		absent
gravitation	1	gravity	1	gravity
galvanic		discovery		substance
logarithm		largo		largo
calyx		K.		Calais
polarization		Poland		flower
cephalic		....		syphon
proteid		digestible	6	protoplasm
kinetic		....	43	energy

I. S., female, age 15, 3rd high school year; total high standard values, first test 796, second test 479.

		1st test		2nd test
geography	2	Europe	8	land
participle		Latin	1	English
Waterloo	46	Napoleon	46	Napoleon
refraction		arithmetic	35	light
arithmetic		school		brain
botany	16	plant		life
isomerism		....	3	geometry
Portugal	49	Spain	49	Spain
amoeba	4	zoology		evolution
declension	8	Latin	19	grammar
burette		hair	3	bureau
physics	3	laboratory	1	energy
hyperbole		disease		hyphenated
retina		....		desire
coagulation		....		coefficient
Cervantes		history	1	Dante
franchise		religion	5	suffrage
subtraction	19	arithmetic	19	arithmetic
metabolism		symbol		symbol
predicate	15	grammar	15	grammar
mollusc		....		mole
inquisition	32	Spain	1	religion
amphibious	2	zoology		life
decimal	6	arithmetic	38	fraction
hydraulic		chemistry		trans-mittance
osmosis		....		isosceles
percentage		population	3	part
cerebellum		Latin		temperance
fractions	24	arithmetic	7	parts
titration		Titian		Asia
carbohydrate		botany	9	chemistry
duodenum		....		united
cosecant		Latin		together
biology	18	life		class
Odyssey	52	Homer	1	wandering
vertebrate	4	zoology	27	animal
gravimetric	6	physics	1	gravity
federal	33	government	1	united
morphology	4	science	3	morphine
hypothenuse	9	geometry	9	geometry
Magellan	1	Spain	1	discovery
hexameter	3	geometry		division
meteor	10	astronomy	2	light
momentum	8	physics		distance
Cornwallis		Lafayette	7	surrender
protozoon	8	zoology		protein
syntax		Latin		reason
distillation		health		man
pollen	6	botany	36	flower
peninsula	10	geography		extension

		1st test		2nd test
binomial		arithmetic		united
crustacean	5	zoology		defended
Bonaparte	9	France		glory
meridian	4	latitude		division
chlorophyll	3	botany		chemistry
tetrahedron		Latin		roof
Madagascar	5	geography		colonies
corolla	34	flower	1	coral
ventral		door		entrance
Belgium		starvation		injustice
tangent	6	geometry		meeting
dorsal		....		door
colloid		....		collar
equator	1	Brazil	1	heat
judiciary	9	court	2	justice
synthesis		....		cynical
Athens	72	Greece		art
epithelium		English		epigram
feudalism	2	England		nobles
coefficient	1	physics	7	exponent
perennial		Latin	27	annual
plebeian	4	Rome		class
catalytic	1	Catiline		capitalists
embryo		botany		chemistry
spectrum		ghost		spectre
continent	18	America		division
spore		hygiene		outlet
theorem	26	geometry	3	problem
Himalaya	1	geography		height
Renaissance	13	Italy	2	learning
quotient	7	arithmetic	2	result
oxidation	17	oxygen	1	air
haemoglobin		disease		globe
axiom		axis	1	fact
Amazon	7	Brazil		wilderness
isosceles	81	triangle		balanced
cohesion	8	physics	5	attraction
protoplasm		botany	4	biology
centrifugal		....	33	force
molecule	1	physics	8	particle
cotyledon	8	botany	1	biology
abscissa		....		absinthe
gravitation	6	physics	18	Newton
galvanic		Gaul		magnetism
logarithm		lumbering		allegory
calyx	5	botany		protection
polarization		cold		distribution
cephalic		....		sepal
proteid	1	physiology		nourished
kinetic	43	energy	11	motion

H. R., female, age 16, fourth high school year; total high standard values, first test 900, second test 1285.

		1st test		2nd test
geography	2	school		America
participle	17	grammar	17	grammar
Waterloo	46	Napoleon	46	Napoleon
refraction	3	physics	35	light
arithmetic		fractions	11	algebra
botany	8	flowers	16	zoology
isomerism		science		science
Portugal	1	Europe	49	Spain
amoeba	4	biology		botany
declension	4	nouns	19	grammar
burette		barette		hair
physics	1	heat	3	electricity
hyperbole	19	exaggeration	19	exaggeration
retina		material	80	eye
coagulation		together	1	condensation
Cervantes		Greek	42	Don Quixote
franchise	5	suffrage	5	suffrage
subtraction	19	arithmetic	19	arithmetic
metabolism		statics		science
predicate	28	subject	5	sentence
mollusc		Japan	8	animal
inquisition	32	Spain	32	Spain
amphibious	5	fish	5	fish
decimal	2	fractions	6	arithmetic
hydraulic	4	physics	38	water
osmosis	1	breathing	1	breathing
percentage		marks	1	mark
cerebellum	2	anatomy	2	anatomy
fractions	24	arithmetic	24	arithmetic
titration		science		....
carbohydrate	1	water	33	sugar
duodenum	1	two		....
cosecant	7	geometry	7	geometry
biology	6	animals	15	zoology
Odyssey	52	Homer	52	Homer
vertebrate	2	spine	2	spine
gravimetric		science		science
federal	2	national	2	national
morphology	1	medicine	4	science
hypothenuse	9	geometry	9	geometry
Magellan	1	exploration.		circumnavigation
hexameter	2	polygon	5	six
meteor	10	astronomy	8	comet
momentum		time	9	speed
Cornwallis	2	history	9	revolution
protozoon	27	amoeba	4	biology
syntax	57	grammar	57	grammar
distillation		adulteration	20	water
pollen	4	flowers	36	flower

		1st test		2nd test
peninsula	25	island	3	Italy
binomial	2	polynomial.	7	algebra
crustacean	1	fish	1	fish
Bonaparte	9	France	9	Waterloo
meridian	4	latitude		division
chlorophyll	36	green	36	green
tetrahedron		three		biology
Madagascar	44	island	44	island
corolla		beads	34	flower
ventral		medicine		throat
Belgium	3	Germany	3	Germany
tangent	6	geometry	6	geometry
dorsal		body	2	anatomy
colloid		physics		- -
equator	1	heat	2	center
judiciary	2	justice	3	judges
synthesis	1	grammar	5	combination
Athens	72	Greece	72	Greece
epithelium		Greek		body
feudalism		nobles	4	mediaeval
coefficient	5	algebra	5	algebra
perennial	3	time	2	year
plebeian		worker	10	patrician
catalytic	11	chemistry	11	chemistry
embryo	6	young	6	young
spectrum		zoology		eye
continent	18	America	18	America
spore	2	reproduction	2	botany
theorem	26	geometry	1	axiom
Himalaya	31	mountains	1	China
Renaissance	2	awakening.	8	art
quotient	7	arithmetic	16	division
oxidation	1	air	15	chemistry
haemoglobin		science		- -
axiom	2	statement		apothem
Amazon	12	woman	12	woman
isosceles	81	triangle	81	triangle
cohesion	5	attraction	2	together
protoplasm	3	substance	3	substance
centrifugal		circle	33	force
molecule	5	small	5	small
cotyledon		science		science
abscissa		disease	5	geometry
gravitation	15	earth	3	pull
galvanic		heat		physics
logarithm	3	algebra	11	mathematics
calyx	2	flowers	2	flowers
polarization		bees	4	physics
cephalic		science		science
proteid	32	food	32	food
kinetic	11	theory	11	theory

W. H., male, age 16, 4th high school year; total high standard values, first test 1474, second test 1219.

		1st test		2nd test
geography	10	history	10	history
participle	28	verb	15	noun
Waterloo	46	Napoleon	46	Napoleon
refraction	11	reflection	11	reflection
arithmetic	3	spelling	3	spelling
botany	2	biology	2	biology
isomerism	4	crystal	4	crystals
Portugal	49	Spain	49	Spain
amoeba	3	cell		molecule
declension	29	noun	29	noun
burette	11	pipette	11	pipette
physics	36	chemistry	36	chemistry
hyperbole	9	parabola	9	parabola
retina	80	eye		cornea
coagulation		boiling		protoplasm
Cervantes	25	Spain	42	Don Quixote
franchise	5	suffrage	1	freedom
subtraction	41	addition	41	addition
metabolism		....		- -
predicate	2	object	2	object
mollusc	3	fish	16	clam
inquisition	32	Spain	32	Spain
amphibious		toad	28	frog
decimal	38	fraction	38	fraction
hydraulic	38	water	38	water
osmosis	4	plants	20	membrane
percentage	8	fraction	8	fraction
cerebellum	16	cerebrum	16	cerebrum
fractions	9	decimal	13	decimals
titration		....		- -
carbohydrates	11	starch		proteid
duodenum	2	twelve		octavo
cosecant	12	sine	12	sine
biology	6	botany	15	zoology
Odyssey	52	Homer	52	Homer
vertebrate	15	invertebrate	3	man
gravimetric	12	weight	1	gravity
federal	7	constitutional	2	national
morphology	3	biology		sleep
hypothenuse		side		arm
Magellan	52	straits	52	straits
hexameter	5	six	4	pentameter
meteor	29	star	29	star
momentum	17	force		acceleration
Cornwallis	25	Yorktown	25	Yorktown
protozoon	2	cell	3	protoplasm
syntax	57	grammar		declension
distillation	5	evaporation		fermentation
pollen	4	fertilization	4	anther
peninsula	25	island	25	island
binomial	2	trinomial	2	trinomial

		1st test		2nd test
crustacean	22	crab	22	crab
Bonaparte	9	France	9	Waterloo
meridian	3	equator	9	longitude
chlorophyll	5	plants	11	leaf
tetrahedron		poetry	3	polyhedron
Madagascar	44	island	44	island
corolla	34	flower	1	sepal
ventral		blood	1	auricle
Belgium	10	Brussels	2	Albert
tangent	10	cotangent	10	cotangent
dorsal	8	fin		caudal
colloid		....	1	collodium
equator	8	meridian	8	meridian
judiciary	25	judge	2	justice
synthesis	39	analysis	39	analysis
Athens		Homer		Minerva
epithelium		....		- -
feudalism		duke	1	knighthood
coefficient	7	exponent	7	exponent
perennial	27	annual	4	biennial
plebeian	3	aristocrat	3	aristocrat
catalytic		....	3	platinum
embryo		fertilization	10	egg
spectrum	2	spectroscope	2	spectroscope
continent	28	island	28	island
spore	16	seed	16	seed
theorem	3	problem	3	problem
Himalaya		Alps		Alps
Renaissance	2	Reformation	2	Reformation
quotient		predicate	3	dividend
oxidation	13	reduction	13	reduction
haemoglobin	84	blood	84	blood
axiom	1	rule		scholium
Amazon		equator	6	South America
isosceles		oblique		equilateral
cohesion		separation	27	adhesion
protoplasm	14	cell	9	amoeba
centrifugal	27	centripetal	27	centripetal
molecule	47	atom	47	atom
cotyledon	8	botany		monocotyledonous
abscissa	4	mathematics		mantissa
gravitation	1	gravity	1	gravity
galvanic	24	electricity	7	cell
logarithm	11	mathematics	1	exponent
calyx	41	flower	2	sepal
polarization	4	physics		fertilization
cephalic		....		- -
proteid	3	albumen	1	carbohydrate
kinetic	2	static	2	potential

The question of the influence of the factor of sex in our test has interested us from the beginning and, in making our arrangements for the collection of material, we endeavored as far as seemed practicable to secure data that might be useful in this connection. These data are summarized in Table 6.

In the course of our experience in this work we have come to regard the total high standard value as a more significant and more trustworthy measure of intellectual condition than any of the others made available by the test, i.e., number of common reactions, individuality index, failure index, etc.

Of the nineteen groups of subjects represented in Table 6, the male subjects made a better showing in average high standard value in nine, and the female subjects in ten groups; in other words, no difference in this respect is apparent between the sexes.

But the other measures revealed a difference in a strikingly consistent way. When a subject is unable to respond to a given stimulus word with a reaction possessing high standard value, he may either respond with a common reaction not possessing such value or with an individual reaction, or he may fail to react. The table shows that in eighteen of the nineteen groups of subjects the males showed a greater tendency than the females to follow the first alternative, i.e., of giving a common reaction possessing no high standard value or an individual reaction, rather than failing to react.

Considering the fact that this tendency is shown, in our material, at all ages from nine years up and under various conditions of amount of education and selection of subjects, it would seem that we are dealing here with a true difference between the sexes in mental constitution. Perhaps this is a manifestation of the relative passivity, conservatism, lack of venturesomeness, and other such traits popularly attributed to the female sex.

TABLE 6.

Description of subject groups.	Grade in school or amount of education.	Sex		Averages. Common reactions.	High standard value.	Individuality index.	Failure index.
Pupils at school or college.	5th elem. school year	Male	12	24.7	109.1	0.454	1.183
		Female	13	23.8	125.8	0.320	1.673
	6th elem. school year	Male	13	22.9	152.0	0.204	2.055
		Female	12	21.1	133.4	0.200	2.166
	7th elem. school year	Male	12	34.2	217.7	0.317	1.089
		Female	13	25.7	135.5	0.313	1.519
	8th elem. school year	Male	13	38.1	337.2	0.218	1.886
		Female	12	37.5	339.3	0.261	1.064
	1st high school year	Male	13	50.4	516.3	0.233	0.624
		Female	12	51.2	423.2	0.205	0.726
	2nd high school year	Male	12	69.1	650.8	0.161	0.239
		Female	13	66.7	675.1	0.159	0.324
	3rd high school year	Male	12	77.0	857.6	0.145	0.113
		Female	13	71.9	738.8	0.078	0.301
	4th high school year	Male	13	82.2	1081.1	0.081	0.103
		Female	12	75.8	820.8	0.086	0.206
	1st college year	Male	12	85.3	1201.6	0.061	0.084
		Female	13	80.3	1259.4	0.042	0.177
	2nd college year	Male	13	85.9	1188.6	0.092	0.040
		Female	12	83.4	1257.4	0.075	0.087
	3rd college year	Male	12	84.3	1188.9	0.081	0.066
		Female	13	83.3	1344.9	0.101	0.078
	4th college year	Male	13	84.8	1091.5	0.116	0.025
		Female	12	85.8	1366.3	0.069	0.044
Adult subjects long out of school.	4 elem. school years	Male	13	21.5	147.7	0.259	1.867
		Female	12	19.9	171.1	0.184	2.315
	6 elem. school years	Male	13	28.8	264.7	0.222	1.585
		Female	12	25.3	221.0	0.195	1.929
	8 elem. school years	Male	12	36.2	305.1	0.284	0.978
		Female	13	27.2	215.8	0.226	1.746
	4 high school years	Male	6	71.9	932.0	0.084	0.307
		Female	19	74.2	1023.2	0.136	0.378
	4 college years	Male	12	86.3	1353.8	0.079	0.034
		Female	13	85.4	1212.0	0.063	0.059
	Holding Master's degree	Male	12	85.6	1393.9	0.111	0.027
		Female	13	92.2	1518.5	0.038	0.040
	Holding Doctor's degree	Male	15	86.7	1452.5	0.109	0.016
		Female	10	83.4	1291.3	0.107	0.047

The small figures in the third column indicate the number of subjects in each group.

PART III. CERTAIN SELECTIVE INFLUENCES AND EFFECTS OF SELECTION.

The factor of selection, as influencing the results shown by various groups of subjects represented in our material, has already been referred to; but its importance seems to be sufficient to warrant special consideration.

The participation of a subject in a given type of activity may be regarded, *a priori,* as evidence of his possession of a certain fitness for it; similarly, his advancement in it may be regarded to some extent as a measure of the fitness. This must, of course, apply to education and scientific pursuits as to any other type of activity.

Thus, every group of subjects distinguished according to amount of education is a selected group which may be expected to show not only the influence of the given amount of education but also that of native mental qualities which go to make up the fitness for it.

This principle of selection by fitness may be readily demonstrated in connection with some of the groups represented in our material.

Table 7 shows the marked contrasts that there are between groups representing approximately the same amounts of education but variously selected according to fitness for education or scientific pursuits as assumed from the fact of continuance or interruption of scholastic work or of advancement in scientific standing.

Thus, adults, whose total education has consisted of eight elementary school years, stand below first year high school students tested at the beginning of the term, who have had, of course, approximately the same amount of education but are distinguished by the fact of continuing their work at school.

Similarly, adults who have had a full high school education stand below college freshmen; and college graduates stand below

TABLE 7.

	AVERAGES.	
Subject groups. (25 subjects in each group.)	Common reactions.	High standard values.
Adults, education eight elementary school years	31.5	258.6
First year high school students	50.3	471.6
Adults, full high school education	73.7	1001.7
First year college students	82.7	1231.6
College graduates	85.8	1280.1
Persons holding Doctors' degree, not in scientific directory	85.4	1388.0
Mentioned in "American Men of Science," not "starred"	90.0	1479.2
"Starred men"[1]	90.7	1625.0

those who have undertaken graduate work and received a Doctor's degree. In the last instance, particularly, it would seem certain that the difference is not in any appreciable degree due to education, inasmuch as the influence of education, as far as this test is concerned, apparently ceases in the first collegiate year.

Perhaps even more significant are the differences between the last three groups represented in the table. The subjects whose names appear in Cattell's "American Men in Science" stand above those who have gained the Doctor's degree but are not mentioned in the scientific directory; the leaders in science, the "starred men" in Cattell's book, stand above those who are not "starred."

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[1] In scoring "starred men's" records for the statistics of this table it was necessary to make allowance for the fact that the test record of each subject entered into the formation of the "high standard." The corrected "total high standard value" for each test record in this group was calculated according to this formula: $v - 100 + \frac{v - 100}{99} = v_1$.

In this formula v represents the uncorrected, and v_1 the corrected total high standard value. The 100 points deducted from v correspond to the contribution of each test record toward the "high standard," which must be eliminated in order that the given test record may not be scored by a standard partly represented by itself. The addition of $\frac{v - 100}{99}$ constitutes an allowance for an average "high standard" test record which must be added to the remaining 99 test records in order that the scoring might still be based on a standard representing a full 100 test records.

It is, however, by no means to be supposed that the selection is perfect, or that fitness alone determines it.

In the first place, it is to be noted that the positive effects of selection appear to be more accurate than its negative effects. Thus, the group of adults who have had but four elementary school years of education, with its average high standard value of 158.9, presented an average deviation of 129.8, or 81.8 per cent; for the group of elementary school graduates the average deviation amounted to 55.2 per cent; for high school graduates, 26.7 per cent; for college graduates, 22.4 per cent; for those who hold a Doctor's degree but are not mentioned in the scientific directory 24.4 per cent; for those mentioned in the directory but not "starred," 17.0 per cent; and for the group of "starred men," 14.3 per cent. In other words, with but one exception, at every step upwards in the scale the positive phase of selection is characterized by a reduction of the relative extent of deviation from the average high standard value.

But it is mainly through an examination of individual test records that the inaccuracy of the selection, both in its positive and negative phases, is clearly brought to light.

Assuming that the total high standard value as revealed by our test is, in this connection, a fairly reliable index of what we have called fitness (its limitations in this respect will be discussed farther on), it is significant that two subjects in the group of "starred men" represented in Table 7 furnished test records whose high standard values were lower than the average for college graduates; while four subjects in the group of college graduates represented in the same table furnished test records whose high standard values were higher than the average for "starred men."

Similarly, one subject in the group of college graduates furnished a test record whose high standard value was 910,—lower than the average for high school graduates—while one in the group of adults, high school graduates, furnished a record whose high standard value was 1614,—nearly up to the average for "starred men."

PART IV. MEASUREMENTS MADE IN CASES OF INSANITY.

As stated in the beginning, this work was undertaken mainly owing to a need, felt in practical psychiatry, for standardized methods of mental measurement. This Part is to consist in a presentation of material collected from certain groups of insane subjects in comparison with norms given in Part II.

Our interest has centered particularly on dementia praecox, manic depressive psychoses, paranoic conditions, and epilepsy.

It is now widely recognized that impure or transition forms of these psychoses exist. In selecting material we tried to find, as far as possible, cases of well established diagnosis, and to eliminate "allied to dementia praecox," "allied to manic depressive psychoses," and other conditions exhibiting atypical traits of symptomatology or course. Among the manic-depressive psychoses, however, we included cases of so-called involutional melancholia.

In order that our pathological material might be comparable with our norms in respect to education only subjects who had received their education in American schools were selected; a number of subjects had to be excluded, however, whose education, though received in this country, was largely private, or irregular, or for other reasons not to be accurately evaluated. Also subjects whose education amounted to less than four elementary school years were excluded.

As we were interested in native mental capacity and not in results of psychotic disease, we sought out cases, as far as possible, of recent onset and free from evidences of mental deterioration. Many subjects had to be excluded who were either unwilling or unable to cooperate fully in the test by reason of very active psychotic minifestations or any other cause.

Among insane subjects commonly, and among apparently normal subjects occasionally, as has been shown, some are met with who present unusual associational mechanisms which are characterized by an unduly marked tendency to respond with individual reactions in free association tests. This tendency, in connection with the present test, must be carefully distinguished from that which also frequently results in large numbers of individual reactions but which is based on limitation of mental capacity and not on unusual associational mechanisms.

In order to exclude from our pathological material cases in which a poor showing in the test might be made by reason of such unusual associational tendency and not limitation of mental capacity, we gave to all cases, as a preliminary, the Kent-Rosanoff test; those which gave, by that test, more than fifteen individual reactions were excluded.

The result was a selection of 205 cases classified as follows:

Dementia praecox	120
Manic-depressive psychoses	49
Paranoic conditions	20
Epilepsy	16

It will readily be judged that our manner of selection has been such that the resulting material could by no means be regarded as truly representative of the clinical groups investigated. Although there are at the Kings Park State Hospital over 4,500 patients and an admission rate of over 1,000 a year, we were compelled to seek cases at the Brooklyn, Manhattan, and Central Islip State Hospitals before we could gather even the small amount of clinical material represented in our study. The fact is that the clinical groups studied by us are well known to contain much larger proportions of subjects who have shown early in life low degree of educability or other evidence of mental disability than are to be found in the unselected population at large. Such mental disability, however, is hardly an essential part of the clinical picture in any of these groups and may rather be regarded as a complication the main significance of which is due to its great frequency,—a matter which need not occupy us here.

Our selected material may, accordingly, be expected to show only what influence, upon the showing in the test employed by us, has the existence of dementia praecox, a manic-depressive constitution, a paranoic condition, or epilepsy, as such, i.e., independently of the frequently observed complications of original inferiority, or acquired deterioration, or both.

For convenience in presentation our material may be divided into two parts: that obtained from subjects who had had not more than a complete elementary school education (Table 8), and that obtained from subjects who had had more than a complete elementary school education (Table 9). The numbers in the tables represent averages for each group.

Among the 11 cases of paranoic conditions represented in Table 8 there were: 1 with an education of four, 1 with five, 2 with six, 6 with seven, and 1 with eight elementary school years. The figures for normal adults given for comparison with this group have been derived by calculation based on averages for subjects of corresponding amounts of education.

Among the 11 cases of epilepsy represented in Table 8 there were: 2 with an education of four, 3 with five, 1 with six, 4 with seven, and 1 with eight elementary school years. The figures for normal adults given for comparison with this group, also those given for comparison with all groups of neuropathic cases, have been derived in the manner already described in the preceding paragraph.

It will be seen from Table 8 that our neuropathic groups, with the sole exception of epilepsy, have furnished higher averages of common reactions than our normal groups. This showing is evidently associated with a tendency to furnish also greater numbers of individual reactions and fewer failures of reaction and is perhaps in a measure to be attributed to the lowered inhibition which is so characteristic of neuropathic subjects in general.

It has already been demonstrated that a similar tendency to give higher numbers of common and individual reactions and fewer failures of reaction is shown by male subjects as compared with female ones; but in this case the showing is not to be attributed to sex, as 83 of the 165 neuropathic subjects were women and the sexes were equally represented in the normal groups used for comparison.

It would seem, then, that there is in normal subjects, inde-

TABLE 8.

EDUCATION	Clinical groups.		Common reactions.	High standard value.	Individuality index.	Failure index.
4 elem. school years	Dementia parecox	16	24.8	151.6	0.371	1.445
	Manic-depressive	2	30.5	186.0	0.166	1.979
	Normal adults	25	20.7	158.9	0.223	2.082
5 elem. school years	Dementia praecox	10	22.2	140.7	0.399	1.410
	Manic-depressive	5	44.2	283.8	0.331	0.494
6 elem. school years	Dementia praecox	33	32.9	229.2	0.472	0.847
	Manic-depressive	15	36.2	195.0	0.350	0.886
	Normal adults	25	27.1	240.1	0.209	1.750
7 elem. school years	Dementia praecox	25	39.6	301.4	0.358	0.636
	Manic-depressive	8	43.1	356.3	0.224	1.016
8 elem. school years	Dementia praecox	20	46.1	429.2	0.292	0.549
	Manic-depressive	9	51.0	425.8	0.183	0.573
	Normal adults	25	31.5	258.6	0.253	1.377
Mixed groups	Paranoic conditions	11	42.1	344.4	0.266	0.968
	Normal adults		28.1	239.4	0.226	1.645
	Epilepsy	11	25.0	97.8	0.553	0.850
	Normal adults		27.0	224.7	0.228	1.705
All groups	Neuropathic cases	165	36.3	265.3	0.363	0.879
	Normal adults		27.4	231.8	0.226	1.689

The small figures in the second column indicate the number of subjects in each group.

pendently of sex, an inhibiting mechanism which is lacking in neuropathic subjects and which is distinct from the somewhat similar inhibiting mechanism existing in the female and lacking in the male sex.

The high standard values appear, on the whole, slightly lower for dementia praecox, higher for manic-depressive psychoses and paranoic conditions, and distinctly lower for epilepsy than for groups of normal subjects of corresponding amounts of education. The differences are not very striking if we leave out of consideration the groups of cases which are too small for trustworthy results. It is clear, therefore, that, as far as subjects of elementary education are concerned, the existence of one of the neuropathic conditions here considered, with the possible exception of epilepsy, does not in the average case affect unfavorably the showing in the test as regards high standard value.

A comparison of the dementia praecox with the manic-depressive groups shows that the individuality index is uniformly higher and the number of common reactions lower in dementia praecox.

TABLE 9.

Clinical groups.		Common reactions.	High standard value.	Individuality index.	Failure index.
Dementia praecox	16	58.9	664.4	0.204	0.468
Normal subjects		75.6	941.1	0.117	0.395
Manic-depressive	10	65.3	741.3	0.125	0.328
Normal subjects		73.3	886.9	0.127	0.276
Paranoic conditions	9	59.9	591.0	0.285	0.160
Normal subjects		76.2	975.6	0.108	0.316
Epilepsy	5	51.4	418.8	0.325	0.374
Normal subjects		74.9	936.8	0.120	0.256
All neuropathic cases	40	59.8	636.4	0.218	0.352
Normal subjects		75.0	934.8	0.153	0.359

We may now turn to Table 9 in which is represented the material obtained from subjects of higher than elementary school education.

Among the sixteen cases of dementia praecox represented in this table there were 4 with an education of one, 3 with two, 1 with three, and 4 with four high school years; and 1 with two, 1 with three, and 2 with four collegiate years.

Among the 10 cases of manic-depressive psychoses there were 3 with an education of one, 2 with two, 2 with three, and 2 with four high school years, and 1 with a full collegiate education.

Among the 9 cases of paranoic conditions there were 2 with an education of two, 2 with three, and 4 with four high school years, and 1 with two collegiate years.

Among the five cases of epilepsy there were 1 with an education of one, 1 with two, and 2 with four high school years, and 1 with one collegiate year.

The figures for normal subjects in this table given for comparison with the respective neuropathic groups and with all the neuropathic cases treated in bulk have been calculated in the same manner as those given in Table 8 for comparison with the mixed education groups.

Table 9 shows that the neuropathic groups have furnished fewer common reactions, lower high standard values, and higher individuality and failure indices than normal groups of corresponding degrees of education. This is true of clinical groups considered individually as well as all together.

Thus, the showing made by neuropathic subjects of higher than elementary education is in rather striking contrast with that made by similar subjects who had had not more than an elementary school education.

Is there in neuropathic subjects a failure of full mental maturation or, at the time of transition from immature to adult age, a deterioration in respect to educability? Or, does higher education involve demands upon mentality which are so much greater than those involved in elementary education as to bring out a contrast between neuropathic and normal constitutions which exists at immature as well as adult ages but which the application merely of elementary education fails to reveal? These are questions which suggest tasks for future research but which must, for the present, remain unanswered.

Of the four neuropathic groups here considered the showing most closely approaching that of normal subjects is that of the manic-depressive group; and this is followed by the remaining groups in this order: dementia praecox, paranoic conditions, and epilepsy.

It should be noted that a neuropathic constitution does not preclude the possibility of at least a fairly good showing in this test: 8 of the 40 neuropathic subjects represented in Table 9 furnished high standard values above the normal averages for corresponding degrees of education; these were distributed as follows: 2 cases of dementia praecox (out of a total of 16), 4 cases of manic-depressive psychoses (out of a total of 10), 2 cases of paranoic condition (out of a total of 9), and none among the five cases of epilepsy.

PART V. EVALUATION OF THE METHOD. SUGGESTION FOR BETTER STANDARDIZATION.

In the course of our work some who were assisting us in the collection of material and others who had become interested in the test offered criticisms of our selection of stimulus words: that there is too large a proportion of scientific terms; that some of the words are so seldom used that it is possible for one not to know them and yet have a fair general knowledge of the subjects concerned (*isomerism, colloid, abscissa*); that some words may, through a slight mispronunciation, be mistaken for others much like them in sound (*hyperbole* for *hyperbola, synthesis* for *symphisis*).

We shall show, presently, that very considerable changes in our list of stimulus words could be made with resulting improvement of the method; but these changes have nothing to do with the above mentioned criticisms and would have to be based on purely empirical grounds.

Moreover, within certain limits, the selection of stimulus words is not so important a matter as might appear, the value of the test depending to a greater extent on thoroughness of standardization. The fact that persons of certain education fail to respond to many of the stimulus words because they are scientific terms, perhaps seldom used, and therefore not known to them, need not lead to an underestimation of their mental capacity, provided the showing of each is compared only with that of others of a similar amount and kind of education; and, after all, there is to-day no education without a certain minimum of science.

Also, the fact that some subjects will give to the word *hyperbole* such responses as *curve, mathematics,* and *parabola,* evidently mistaking it for *hyperbola,* will not lead to error, as these responses and others like them have, in the process of standardization, found places in the frequency tables with values probably corresponding to the measure of the chance of misapprehension.

Other criticisms that have been offered pertain mainly to our instruction to subjects to respond with the first word: when two or three words crowd into consciousness almost at once one hardly knows which was the first; some subjects will exercise choice, more or less consciously, in spite of instructions, and thus disturb the uniformity of conditions; the first word aroused by association, being more or less casual, cannot always be regarded as the best indication of the subject's knowledge; reaction time should be recorded or a set limit of time for reaction enforced with the aid of a metronome.

Our main defense of our method consists in the results of its application. That it is burdened with limitations and shortcomings, and the extent to which it is so burdened, we shall try to show as far as possible. We can say at this point, however, that the above criticisms would not seem to be wholly valid.

The difficulty of choosing the first of a rapid succession of words aroused by association we judge to be but rarely experienced, as subjects seldom show any evidences of it and seldom speak of it even when giving an introspective account; therefore we believe any error that may result from this source to be insignificant, except possibly in subjects of unusual mental constitution.

That some subjects may exercise more or less conscious choice, in spite of instructions not to do so, we are not in position to dispute; we do not know how often it happens, but our experience leads us to believe that the instructions, though setting no limit of time for reaction, nevertheless effectually exclude for almost all cases the chance of any considerable conscious deliberation, as may be judged from the fact that the great majority of our adult subjects have completed the test in from fifteen to twenty minutes.

Among the highest scored test records many have been obtained in less than ten minutes; which shows that, if subjects, who have taken a longer time, did so for the purpose of conscious deliberation, they were not necessarily enabled thereby to produce a higher scored result.

It should further be considered that the specificity of the great majority of the responses indicates that they are all the result of choice. The question is, therefore, not as between choice or no choice, but as between unconscious and deliberate choice. Here, it seems to us, a sharp line of distinction could hardly be drawn; and inasmuch as the chance of deliberate choice, as already stated, is generally slight and apparently without demonstrable advantage, any error that might result from this source, too, would seem to be but inconsiderable.

As to the point of the first word aroused by association being more or less casual and not always to be regarded as the best indication of the subject's knowledge, it must be observed that the only other alternative, namely, that of securing the subject's best choice, would be practically impossible of realization: one is at his best mentally probably during but small fractions of his life time. We could, of course, call for the response that might at the time of the test be chosen by the subject as the most appropriate one; but this, it seems to us, would but increase the scope of interference of the uncontrolled variable factor of conscious choice, without at the same time making sure of evoking a response which would be the best indication of the subject's knowledge.

We have considered the advisability of recording the reaction time or of setting a limit of time for reaction with the aid of a metronome, but have decided against it mainly on the grounds of our psychiatric experience; and it will be recalled here that we undertook this work in response to a need which we have come to feel in our psychiatric practice. In formulating the conditions of the test we aimed to secure for the subject the greatest possible freedom from affective tension, such as might be produced by placing any emphasis whatever on reaction time. Such tension, we believe, would probably affect the results in cases of neuropathic subjects, if not in many normal ones as well. The readiness with which such tension develops varies so widely in different individuals that it would seem very doubtful if a gain, rather than a loss, in uniformity of conditions would result from the introduction of a factor of technique which might tend to excite it

Turning again to the question of selection of stimulus words, we submit in Table 10, in connection with each of the stimulus words on our list, the sum of the high standard values of the responses given, respectively, by five groups of normal subjects (25 in each group) which can be readily distinguished from one another according to degree of physiological maturation, amount of education, or mental capacity.

Assuming that the showing should be uninterruptedly progressive in the order of the arrangement of the groups of subjects in the table, it will be noted that the actual showing is not equally consistent with expectation for all the stimulus words.

The stimulus words may, in this respect, be divided into three classes: Class A, for which the showing is entirely consistent with expectation; Class B, for which it is consistent in relation to but four of the five groups of subjects represented in the table; and Class C, for which it is consistent in relation to but two or three groups of subjects.

According to this grouping the stimulus words arrange themselves as follows:

Class A (41 words): *Waterloo, arithmetic, isomerism, Portugal, burette, coagulation, Cervantes, metabolism, inquisition, amphibious, osmosis, titration, duodenum, biology, Odyssey, vertebrate, gravimetric, morphology, Magellan, protozoon, syntax, binomial, crustacean, ventral, dorsal, colloid, synthesis, Athens, perennial, catalytic, spectrum, continent, spore, haemoglobin, protoplasm, molecule, cotyledon, galvanic, polarization, cephalic, kinetic.*

Class B (28 words): *botany, declension, hyperbole, retina, franchise, decimal, percentage, cerebellum, carbohydrate, hypothenuse, hexameter, distillation, chlorophyll, tetrahedron, Madagascar, corolla, Belgium, tangent, epithelium, feudalism, embryo, Renaissance, isosceles, cohesion, centrifugal, abscissa, gravitation, calyx.*

Class C (31 words): *geography, participle, refraction, amoeba, physics, subtraction, predicate, mollusc, hydraulic, fractions, cosecant, federal, meteor, momentum, Cornwallis, pollen, penin-*

TABLE 10.

	5th elem. school year.	1st high school year.	1st college year.	Subjects holding Master's degree.	"Starred Men."
geography	96	191	148	99	149
participle	0	293	305	263	412
Waterloo	6	427	728	772	918
refraction	1	46	436	331	436
arithmetic	20	78	124	193	201
botany	0	182	260	237	288
isomerism	0	0	29	39	238
Portugal	160	252	583	597	665
amoeba	12	0	72	106	102
declension	0	177	447	331	454
burette	21	6	123	141	198
physics	0	91	350	250	317
hyperbole	0	7	150	169	150
retina	0	160	1521	1520	1564
coagulation	0	0	408	617	696
Cervantes	1	7	187	298	710
franchise	6	6	182	119	235
subtraction	49	170	595	550	538
metabolism	1	0	12	82	126
predicate	119	382	570	414	409
mollusc	8	0	68	208	203
inquisition	2	75	255	405	450
amphibious	3	3	140	272	399
decimal	101	337	489	373	564
hydraulic	0	98	506	458	392
osmosis	0	0	38	99	110
percentage	21	96	117	179	121
cerebellum	0	195	1008	1067	1067
fractions	117	160	277	139	261
titration	1	0	75	114	184
carbohydrate	0	23	185	144	227
duodenum	0	2	6	496	766
cosecant	0	0	411	382	210
biology	2	95	128	209	228
Odyssey	6	77	623	715	892
vertebrate	0	50	122	285	389
gravimetric	0	19	69	73	126
federal	0	118	443	230	314
morphology	1	20	32	245	489
hypothenuse	0	195	908	1125	1033
Magellan	13	195	233	532	829
hexameter	2	20	114	96	220
meteor	3	82	330	339	306
momentum	0	9	234	203	186
Cornwallis	12	227	226	145	217
protozoon	14	0	103	230	255
syntax	8	198	754	817	860
distillation	0	81	282	318	156
pollen	109	108	471	392	423
peninsula	202	303	363	268	272
binomial	4	36	545	830	845

TABLE 10—*Continued.*

	5th elem. school year.	1st high school year.	1st college year.	Subjects holding Master's degree	"Starred Men."
crustacean	5	8	105	151	197
Bonaparte	0	354	733	600	559
meridian	41	122	133	134	117
chlorophyll	25	34	209	442	371
tetrahedron	0	7	105	164	106
Madagascar	235	473	560	596	549
corolla	0	254	209	304	376
ventral	3	2	145	220	479
Belgium	72	199	228	289	217
tangent	0	10	201	287	275
dorsal	0	0	252	393	438
colloid	1	2	14	44	95
equator	120	101	176	154	147
judiciary	2	186	320	334	128
synthesis	0	10	128	498	604
Athens	6	469	965	1235	1345
epithelium	1	3	51	750	514
feudalism	0	17	49	72	67
coefficient	0	107	146	124	93
perennial	1	50	153	181	246
plebeian	1	0	299	263	247
catalytic	0	1	55	57	147
embryo	0	4	42	125	103
spectrum	0	0	164	237	309
continent	87	180	240	241	331
spore	0	18	59	79	149
theorem	1	25	451	274	224
Himalaya	192	607	599	710	596
Renaissance	0	3	69	94	78
quotient	12	132	257	124	230
oxidation	0	101	238	200	193
haemoglobin	0	1	507	1265	1734
axiom	0	12	356	273	223
Amazon	918	1242	616	824	899
isosceles	0	891	1716	1503	1760
cohesion	0	12	234	217	275
protoplasm	3	41	84	126	127
centrifugal	0	33	462	565	531
molecule	1	98	398	500	683
cotyledon	5	51	109	203	318
abscissa	0	4	151	124	413
gravitation	0	97	163	213	170
galvanic	0	0	123	264	444
logarithm	0	0	268	231	225
calyx	1	492	513	646	564
polarization	9	6	143	533	698
cephalic	0	0	71	354	507
proteid	0	43	470	321	294
kinetic	0	0	353	517	624

sula, Bonaparte, meridian, equator, judiciary, coefficient, plebeian, theorem, Himalaya, quotient, oxidation, axiom, Amazon, logarithm, proteid.

The figures of Table 10 are presented in summary form, for the three classes of stimulus words here distinguished, in Table 11, wherein each number represents the average sum of high standard values of the responses given by each group of subjects to the stimulus words in the given class.

TABLE 11.

Stimulus words.	5th elem. school year.	1st high school year.	1st college year.	Subjects holding Master's degree.	"Starred Men."
Class A (41 words)	15.36	99.08	375.40	606.36	801.96
Class B (28 words)	18.56	160.48	425.00	482.76	497.92
Class C (31 words)	80.60	212.40	434.68	373.72	372.88
Totals	114.52	471.96	1235.08	1462.84	1672.76

It is to be noted that while, as shown in Table 10, none of the words in Class B elicited a showing entirely consistent with expectation, the showing of the class as a whole, as given in Table 11, is consistent.

It would seem from all this that, while the test is sound in principle, it is capable of considerable improvement through a better selection of stimulus words. The improved selection is to be made only by an empirical method, like that which enabled us to select from amongst our list of one hundred stimulus words those of Class A. In other words, it would be necessary to make a preliminary selection of, say, two hundred additional stimulus words; to apply the test by means of these words to variously selected groups of subjects in order to construct frequency tables and norms representing certain degrees of education, mental capacity, etc.; and finally, to eliminate, with the aid of material thus collected, all words like those of Class C and perhaps even like those of Class B, so that one hundred stimulus words would remain eventually which would correspond as far as possible with our Class A.

The test could probably be further improved if it were practicable to make a stricter selection of subjects whose test records should go to make up the "high standard" represented in the frequency tables. It would be desirable to select not only "starred men" exclusively, but, from amongst them, those whose test records make a showing above the average for their class. This would involve the application of the test by means of, say, 250 provisionally selected stimulus words, as suggested above, to at least 200 "starred men."

Upon being thus improved, the test could still not be applied to individual cases without certain precautions.

Above all it should be borne in mind that the test is not applicable to subjects showing unusual associational mechanisms, especially if characterized by an undue tendency to give individual reactions. Among such subjects are to be found some who are beyond question of very great mental capacity.

One such subject, a "starred man," occupying a chair in an important department of one of our leading universities, a man of international standing in science, devoted forty minutes to a conscientious but painful and futile attempt to cooperate in the test and gave it up as hopeless at the end of that time.

Another subject, equally eminent, writes in a personal communication: "My own difficulty is this.—When a word is dropped into me, as stimulus, it is likely first of all to arouse a gross conscious-attitude; then, out of that, there emerge (variously under various circumstances) images, feels, particularized attitudes, word-ideas. The word-ideas (1) are often irrelevant to the direct meaning of the stimulus,—they derive mediately from the attitude; (2) are often incomplete, mere hints of a word; and (3) often carry the meaning not of a single word but rather of a phrase or group of words. I think I may say that the direct word-to-word association is almost unknown to me,—unless I am working under a very pressing instruction as to time; then perhaps I should get individual verbal ideas.—Your instruction, now, calls for the 'first word.' The only way I could meet it would be, I think, by a course of practice during which it (the instruction) was repeated again and again, until I got "mechanised" as a word-associator. That process seems possible; though I am not sure—one cannot be beforehand—that the utterance of the word would ever really represent my immediate response to the stimulus word."

In other cases subjects, apparently cooperating without difficulty, respond very largely with individual reactions. A striking instance is represented by the following test record. It is perhaps significant that no fewer than eight reactions are "doubtful" and that of the forty-nine individual reactions as many as eleven fall into the class of those possessing "value assigned by appendix" (see Part I), namely, *metabolism*—inhibition, *meteor*—surprise, *momentum*—forward, *Bonaparte*—leader, *synthesis*—fusion, *plebeian*—despicable, *embryo*—hormone, *axiom*—reason, *cohesion*—aggregation, *centrifugal*—approach, and *molecule* analysis.

Male, age 38, "starred man," has made important contributions to science, eminent both as teacher and as investigator, has been elected to offices and has received appointments indicating general recognition in competent circles of his scientific attainments.

This test record has an apparent total high standard value of 456. As it has served, with our other "starred men's" records, for the construction of the "high standard" on which the scoring of its reactions is based, a correction is required. The corrected total high standard value is 360, calculated according to the formula already given (Part III):

$$456 - 100 + \frac{456 - 100}{99} = 360.$$

geography	6	book	binomial	1	accuracy
participle	17	grammar	crustacean	1	development
Waterloo	46	Napoleon	Bonaparte	1	leader
refraction	35	light	meridian	1	artificial
arithmetic	1	books	chlorophyll	1	composition
botany	1	sensibility	tetrahedron	5	form
isomerism	28	chemistry	Madagascar	1	travel
Portugal	1	war	corolla	1	morphology
amoeba	1	light	ventral	1	picture
declension	29	noun	Belgium	1	university
burette	2	fluid	tangent	1	relation
physics	1	refraction	dorsal	1	opposite
hyperbole	10	curve	colloid	1	teleology
retina	1	cell	equator	1	central
coagulation	48	blood	judiciary	1	crime
Cervantes	1	novel	synthesis	1	fusion
franchise	1	right	Athens	1	war
subtraction	1	process	epithelium	1	protection
metabolism	1	inhibition	feudalism	1	armament
predicate	25	verb	coefficient	1	index
mollusc	11	shell	perennial	2	year

inquisition	1	century	plebeian	1	despicable
amphibious	2	batrachian	catalytic	1	psychology
decimal	38	fraction	embryo	1	hormone
hydraulic	13	press	spectrum	1	divisions
osmosis	2	water	continent	1	science
percentage	2	mathematics	spore	1	individual
cerebellum	1	irritability	theorem	3	problem
fractions	13	decimals	Himalaya	1	space
titration	1	accuracy	Renaissance	1	genetic
carbohydrate	2	nutrition	quotient	1	outcome
duodenum	1	rhythm	oxidation	1	progress
cosecant	3	angle	haemoglobin	1	corpuscle
biology	12	science	axiom	1	reason
Odyssey	11	Greek	Amazon	1	parrot
vertebrate	1	classification	isosceles	1	generalization
gravimetric	1	psychometric	cohesion	1	aggregation
federal	1	laws	protoplasm	1	analysis
morphology	1	fashion	centrifugal	1	approach
hypothenuse	1	visual	molecule	1	analysis
Magellan	2	geography	cotyledon	1	part
hexameter	1	measure	abscissa	1	description
meteor	1	surprise	gravitation	1	molecular
momentum	1	forward	galvanic	1	laboratory
Cornwallis	1	peace	logarithm	1	Chauvenet
protozoon	8	zoology	calyx	5	botany
syntax	1	science	polarization	1	apparatus
distillation	1	research	cephalic	1	neurology
pollen	4	fertilization	proteid	1	bio-chemistry
peninsula	1	description	kinetic	1	activity

In a given case the question of the presence of unusual associational tendencies, such as are here referred to, and others as well, can be determined by the application of the Kent-Rosanoff test, as we have done in selecting our pathological material.

The possibility of a poor showing attributable to a temporary condition of the subject (see Part II) must also always be considered. A safer judgment in a given case could perhaps be arrived at by giving the test two or three times at intervals of, say, three months, and using the test record with the best showing.

A small portion of the material in our possession suggests that a good showing in the test is not necessarily an indication of a mental constitution which would insure in the given case a career of productiveness and achievement even in spheres of purely scholastic or scientific activity. It would seem to indicate merely the possession of certain elements of mental constitution which bear a highly important relationship to such achievement.

We are led to say, then, that in the individual case the test, even in the most improved form conceived by us and in spite of the above suggested precautions, will not furnish an absolutely conclusive result. We offer it merely as a material aid, to be used in connection with other methods of investigation, in measuring mental capacity. Just as, for instance, no physician undertaking the investigation of a case of syphilis could reasonably limit himself to the application of the Wassermann reaction, so no one undertaking the investigation of the mental constitution of a human subject could reasonably limit himself to the application of this or any other single test.

PART VI. SUMMARY.

1. Our special problem was to develop a free association test, to be applied by means of a specially selected list of stimulus words, whereby a subject's mental capacity might be estimated from a measure of what he has acquired in the course of his education in comparison with the average acquisition of a group of subjects of the same amount of education.

2. In selecting the stimulus words we were guided mainly by the standard curricula of American schools.

3. Test records from one thousand subjects of at least full collegiate education served for the construction of frequency tables; among these were one hundred specially qualified subjects, listed in Cattell's "Amercan Men of Science," more than half of them "starred man," whose test records served for the development of a "high standard," rendering possible a more accurate evaluation of reactions.

4. In scoring test records we have found the following measurements to be apparently of most significance: a. Sum of "high standard" values; b. Number of common reactions; c. Individuality index, i.e., a measure of the tendency to respond with individual reactions; and d. Failure index, i.e., a measure of the tendency to fail to respond.

5. Three hundred test records were secured from pupils in the elementary schools, high schools, and colleges in New York City, which served for the construction of a scale of norms.

6. One hundred test records were secured from adults of various degrees of education below college for comparison with those obtained from younger subjects for the purpose of gaining some idea of the influence of the factor of physiological maturation.

7. As far as this test is concerned, the results are influenced by the factor of education up to, but not beyond, the first year in college.

8. Native mental capacity influences the results very markedly, as is shown by the wide variations in groups approximately homogenous in respect to education.

9. The factor of physiological maturation can be shown to have an influence up to the age of eleven years, but not beyond.

10. The influence of another factor can be demonstrated, which may be termed *temporary condition of the subject.*

11. All conditions being approximately equal, no difference is found in the showings of the two sexes as regards our most significant measure,—the sum of "high standard" values; but male subjects show very consistently a tendency to give either individual reactions or common reactions having no "high standard" value where female subjects furnish failures of reaction instead.

12. Variously selected groups of subjects show, independently of education, striking contrasts in the results of this test. Especially interesting in this connection is the fact that subjects listed in Cattell's "American Men of Science," but not "starred," make a showing superior to those who have gained a Doctor's degree but who are not listed; while "starred men" make a showing superior to those not "starred."

13. Our pathological material consists of 205 selected cases of dementia praecox, manic-depressive psychoses, paranoic conditions, and epilepsy. The subjects were classified into two groups: those who had had not more, and those who had had more, than an elementary school education.

14. As far as the elementary education group is concerned, the existence of one of these neuropathic conditions (free, by selection, from mental deterioration or unusual associational mechanisms), with the possible exception of epilepsy, does not affect unfavorably the showing in the test as regards sum of "high standard" values; but a tendency to give individual reactions or common reactions without "high standard" value, where normal subjects give failures of reaction, seems to characterize all the groups of neuropathic subjects independently of sex.—It would seem that there is in normal subjects, independently of sex, an inhibiting mechanism which is lacking in neuropathic subjects

and which is distinct from the somewhat similar inhibiting mechanism existing in the female and lacking in the male sex.

15. As far as the higher than elementary education group is concerned, the showing of neuropathic subjects falls very distinctly below that of normal subjects.

16. Of the four neuropathic groups considered the showing most closely approaching that of normal subjects is that of the manic-depressive group; and this is followed by the remaining groups in this order: dementia praecox, paranoic conditions, and epilepsy.

17. In Part V. an attempt is made to evaluate the method in the light of the results. Certain criticisms and suggestions which have been made are discussed. It appears that only 41 of the 100 stimulus words on our list are well suited for our purpose; 28 others are less well suited, yet give a result on the whole fairly consistent with expectation; the remaining 31 are ill suited.—The test is capable of improvement through a better selection of stimulus words by an empirical method which readily suggests itself.

18. The test could probably be further improved by a stricter selection of subjects whose test records should go to make up the "high standard" in the frequency tables. Should a restandardisation be attempted it would be desirable to select for his purpose only "starred men" to begin with and then, from amongst them, those whose showing in the test is above the average for their class.

19. This test is not applicable to subjects showing unusual associational mechanisms. In a given case the question of the presence of such mechanisms can be decided by the application of the Kent-Rosanoff test.

20. In a given case, in order to eliminate the possible disturbing influence of the factor which we have termed *temporary condition of the subject,* it might be well to apply the test two or three times at intervals of about three months and use the test record with the best showing.

21. A good showing in the test does not necessarily indicate a mental constitution which would insure in the given case a

career of productiveness and achievement, but only the possession of certain elements of mental constitution which bear a highly important relationship to such a career.

22. Accordingly, the test is offered not as capable of furnishing a conclusive result in a given case but only as a material aid, to be used in connection with other means of investigation, in measuring mental capacity.

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STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF THE UNIVERSITY OF CHICAGO

An Experimental Study of Attention from the Standpoint of Mental Efficiency:

A Contribution to Educational and Social Problems

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CHAPTER I.

PROBLEM AND METHOD.

The problem of the present experimental study is to determine whether or not the so-called concentration of attention, or excessive attention is, as compared with normal attention, favorable to mental work. It is a common opinion that a greater amount of mental work, qualitatively or quantitatively, can be accomplished by the greater intensity of attention. This popular assumption, however, has no adequate scientific proof, and at present, a satisfactory conclusion has not been reached. It is possible that the relative efficiency of various degrees of mental concentration may vary with the kind of problem, the duration of time, and the individual's habits of work.

The importance attached to the present problem is two-fold: educational efficiency on the one hand and social efficiency on the other. The problem of the efficiency of concentration of attention has been much emphasized in modern pedagogy. Skill of teaching depends largely upon a proper control of the attentive process of school children. The present problem also has its practical value when we view it from the standpoint of social efficiency. Since modern society, as the result of division of labor, brings more monotonous work to some than to others, we must adjust ourselves by selecting the more serviceable methods for mental operations and by eliminating undesirable factors for the conservation of human energy. This thesis furnishes, to some extent, information concerning the comparative effectiveness of concentrated and normal attention in monotonous work.

The solution of the problem involves the doing of two things at the same moment, that is, the subject is required to perform the same work, or similar work of comparable difficulty, with different degrees of mental concentration, and at the same time he has to control the degree of attention while the work is being performed. If the attention is directed intensively toward the work, the subjective control of the degree of attention may be slighted; and conversely, if it is directed mainly toward the supervision of the degree of attention, the efficiency of work may be decreased. In either case this type of simultaneous measurement presents methodological difficulties.

From the standpoint of my problem all *objective* means of measuring the degree of attention involved in any piece of work contain certain fatal defects. 1. Certain objective methods may be termed performance or achievement tests. They propose to measure the degree of attention involved in any mental task by the efficiency with which that task is performed. Two arithmetical computations are made with different degrees of attention and these two degrees of attention are measured in terms of the speed and accuracy of the two activities. Any such method cannot be utilized in our experiments, because it assumes the truth of the very proposition we propose to test. 2. The degree of attention to any act, e.g., memorizing, may be measured by means of certain activities incidental to or accompanying that act. Such incidental activities that might be used are breathing, circulation, frowning, involuntary contractions, etc. These comprise what are generally known as the physiological or expression methods. These methods again assume the truth of the proposition to be tested, viz., that a direct quantitative relation obtains between the degree of attention and any of the resulting acts even though of an incidental character. The use of these incidental acts as an index of the degree of attention assumes that these acts are conditioned by one and but one factor,—the degree of attention. 3. The only other possible objective method is to attempt to measure the attention involved in any act A through some other simultaneously induced act B. Distraction tests and Woodrow's Detractor method illustrate this class.

The former i.e., distraction method, presents some sensory stimulus to the subject while engaged in some specified task. The strength of the stimulus is increased until it attracts the attention of the subject away from the task at hand, and this strength of stimulus is regarded as an index of the degree of attention. This procedure contains several defects. The effect on the attention is not always proportional to the intensity of the stimulus, and the effect of any given intensity may vary from time to time.

To eliminate distraction from the measurement of attention, Woodrow[1] proposes another method called "detraction." His method of measuring attention is a simple reaction using unfavorable preparatory intervals for the detractor. This means that he made a substitution of unfavorable preparatory intervals in place of some physical device, such as an alarm-bell, drugs, and other means commonly used in the distraction method.

In his experiments he obtained four different degrees of attention by using four different intensities of light stimuli; namely, bright, dim, quite dim, and very dim. He assumes that[2] "a degree in intensity sufficient to give a large decrease in reaction-time will also condition a lower degree of attention;" in other words,[3] "that the highest degree of attention would be obtained with the greatest intensity of light." It is questionable as to how far this assumption is valid. There is no objection so far as he considers a stimulus a condition of attention, but it is quite doubtful whether or not the highest degree of attention can be obtained from the greatest intensity of the stimulus. His results indicate that a greater intensity of stimulus gives a quicker reaction. But, does a quicker reaction represent a higher degree of attention? This must necessarily be true according to his assumption. Does a strong stimulus always bring forth a high degree of attention? Suppose, for instance, one sees a bright light in a dark place at one time and a very dim light at another; then, must one conclude that a strong light requires a higher degree of attention than a dim one? Or, suppose one hears two musical tones, the first is so loud that everyone can hear it in the hall, while the other is a sweet, soft, low tone; now, must one believe that the former requires, or necessarily elicits, more attention than the latter? It is clearly evident that objective means alone cannot be taken as the criteria for measuring the degree of attention.

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[1] Psychol. Monog. 1914, Vol. XVII, No. 5, p. 10.

[2] *Op. cit.*, p. 71.

[3] *Op. cit.*, p. 72.

Woodrow used a simple reaction as the means of measuring attention, but there is much dispute as to the validity of its use. Some regard the speed of reaction as an index of the degree of attention, while others hesitate to do so. According to Cattell,[4] "ordinary degrees of attention do not greatly affect the length of reaction-time." Binet[5] found the same speed of reaction-time from both intelligent and dull pupils. The use of simple reaction-time as a means of measuring attention may be objectionable on the ground that it tends to become habitual.

Granted the validity of Woodrow's method, it will serve merely to measure the concentration of attention involved in reaction-time. It can hardly be used in measuring attention in some other mental work like memorizing, as in our experiments. Such a procedure would require our subjects to react to some sensory stimulus while engaged in memorizing a series of nonsense syllables. It is doubtful if one would be justified in regarding the speed of reaction-time under these conditions as an index of the degree of the attention given to the mastery of the memory-material.

As already pointed out, objective methods contain various defects for measuring attention, and hence we must search for another method which will not operate as a distraction. The method of measurement must be such that it is an integral part of the attentive work in the actual situation. The means of measurement must be found in subjective terms. This paper aims to determine whether or not a subject can estimate and compare different degrees of attention and identify each from time to time with any approximation to validity. Can one identify the stages of attention and be able to state them as greater or less just as clearly as he can recognize and describe the qualitative aspects of color, as in the case of red and green? This type of measurement implies an introspective analysis for measuring attention.

Before taking up the description of our method, it will be profitable to discuss at some length the experiments of Geissler and Dallenbach, for their works fall in the same line as our own.

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[4] "Reaction-time," Mind, Vol. II, 1886, p. 238.

[5] "Attention et adaptation," Année Psychol. 1899, p. 279.

Geissler, having become dissatisfied with previous methods, attempted to measure the degree of attention in terms of clearness value. His chief contention against the older methods was that "previous investigations had simply assumed that the variations of attention are directly paralleled by certain changes, whether in reaction-time, in muscular pressure, or in quickness and accuracy of work, etc., etc., but they had not attempted to verify this assumption by reference to experimental introspection, and thus their psychological task was only half completed." He then went on "to determine whether and how far the assumed parallelism of the expression methods rested on an experimental basis." He made experiments on motor inhibition, continuous addition, and marking circles. The last experiment was a modification of W. McDougall's method of marking irregularly colored dots or circles; it was an experiment on visual attention, and probably the best in the sense that it fulfilled more requirements for measuring attention than the other two. His subjects were required to do two things simultaneously, e.g. to estimate the degree of attention while some kind of mental work was being performed, or to estimate the quality of work in terms of clearness. The introspective analysis of the degree of attention was worked out in the following scale of nine degrees of clearness.[6]

1. About 90-100% = maximally clear or excellent attention.
2. " 80-90% = very clear or very good attention.
3. " 70-80% = clear or good attention.
4. " 60-70% = fairly clear or fairly good attention.
5. " 50-60% = fair or fair attention.
6. " 40-50% = fairly vague or fairly poor attention
7. " 30-40% = vague or poor attention.
8. " 20-30% = very vague or very poor attention.
9. " 0-20% = absolutely obscure or no attention.

Geissler thinks that[7] "the determination of a difference limen for clearness would be the most important step toward an exact measurement of concentration of attention. It would enable one, by starting with a certain clearness degree of a given mental process under fixed experimental conditions, either to increase or decrease that clearness by just noticeable differences, until the maximum or minimum of attention to the particular process is reached." In conclusion he says:[8] "a very close parallelism was found to exist between introspectively distinguishable variations of attention and the corresponding differences in the precision of work performed at these levels, under the condition that the estimation of degrees of attention was made in terms of clearness and that the work itself was not influenced by anything else but change in attention."

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[6] Amer. Jour., Psychol., Vol. xx, 1909, p. 511.

[7] *Op. cit.*, p. 523.

Psychologically, Geissler's undertaking in the measurement of attention is a promising one, but I must mention a few points regarding it. In the first place I do not agree with his identification of attention and clearness,[9] although I do admit that clearness is one of the characteristic features of attention. The introspective analysis of the degree of attention is a judicious one, but it is a method which cannot be applied to children. From a genetic standpoint, it has serious limitations and cannot be applied universally. In the second place, when we come to face the dynamic side of attention, the category of clearness tends to break down. For instance, in playing tennis, as a ball comes and goes, no one has a single moment for introspection. The degree of attention to objects in motion is hardly to be measured in terms of clearness value. Finally, the last objection, which is not so serious when compared with the other two, is found in regard to some individuals who claim to be imageless. I had one subject who classified himself with the imageless, and in such a case the category of clearness in Geissler's sense has no place.

Dallenbach's[10] work can be regarded as the continuation of that of Geissler. The former attempted to measure the degree of attention in the domain of audition, and the latter in vision. Both used the same terminology in grading the intensity of attention.

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[8] *Op. cit.*, p. 529.

[9] See also Titchener, "Textbook of Psychology," p. 267.

[10] Dallenbach, "The Measurement of Attention," Amer. Jour. of Psych. 1913, pp. 466-507.

We do not know, however, how far one can carry on the terminology of nine degrees of attention in other domains than vision and audition. Is it possible to discriminate nine degrees of clearness in touch, smell, or taste? Is it possible to differentiate nine degrees of attention in the learning process? Theoretically, there may be nine or more degrees of attention, but practically, it is almost impossible to obtain them in every individual, especially in the cases of touch, smell and taste, or in any higher mental process like learning. Furthermore, this type of technique requires a long preliminary training; for instance, one[11] of Dallenbach's subjects took three months to master nine degrees of attention in terms of clearness value.

The standardization of the degree of attention is not an easy task. From the structuralistic point of view, there may be more than nine degrees of attention, but the terms maximally clear, very clear, clear, fairly clear, fair, etc., as used by Geissler, are merely relative and may involve difficulties in identification of the varying degrees. Hence such a system can hardly be utilized up as a standard for measuring attention.

Our method of measuring attention is by no means an entirely new one, but it is an attempt to construct an adequate method for practical as well as theoretical purposes in the light of previous ones. The difference between Geissler's and Dallenbach's experiments and ours is found in two points: one is in connection with the use of technique, and the other, with the character of work chosen. As to our technique, we use but two degrees of attention, e.g. normal attention and concentrated or excessive attention. The distinction between the two is that our subjects work under two different mental attitudes: in normal attention the given task is performed with freedom and natural ease, while for the concentrated or excessive attention the greatest effort must be put forth. Two series of experiments, one for the test of normal attention, the other for that of concentration of attention, are taken in order to compare them from day to day with reference to efficiency of work. This type of technique has certain advantages over previous methods for the following reasons: (1)

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[11] *Op. cit.*, p. 468.

The less the number of degrees of attention, the more valid will be the test because one can compare and identify them with greater accuracy: (2) Everyone knows what is meant by normal attention, and by concentration, and consequently the experiment does not demand a long period of previous training: (3) Such a simple technique enables us to work with children: (4) Its field of work is universal, and it allows us to work with all kinds of materials; (5) and finally, the application of its principal results has practical value for educational as well as for social efficiency.

As to the character of work chosen, our materials are such that they fulfill the following requirements necessary for measuring attention. In the first place, when the experiment requires some sort of apparatus, it must be constructed in such a way that it makes no noise. Of course, one cannot be absolutely free from internal or external distractions at any moment, but the distraction which is caused by any apparatus should be particularly avoided. In the second place, the materials for work must be such as can be completed in a short duration of time in order not to destroy the quality of attention. A short duration of time for work enables us to eliminate, or at least minimize, the effect of fatigue. In the third place, the materials must be such that they can be made equally novel and attractive from day to day. A mere repetition of the same material over and over is seriously objectionable for the measurement of attention because the act tends to become habitual. For this reason reaction-time is not suitable for measuring the efficiency of concentration of attention. In the fourth place, the organization of materials must be such that they can be made of equal difficulty. The unit of work must be clearly defined and carefully standardized; otherwise, the objective result obtained cannot be used for the comparison of different degrees of attention made by subjective estimations. In the fifth place, the materials must be of such a nature that they will permit many exercises of the same kind which will be of equal difficulty, and whose contents can be modified and varied from day to day. These five requirements are essential for any validity of results in measuring the efficiency of concentration of attention.

With these five requirements in mind, three main tasks were chosen. The first one was copying, the second one, adding, and the last one, memorizing nonsense syllables.

The description of each test at the beginning of the following chapters will sufficiently explain how each test fulfils the above conditions. It is obvious that the standardization of each unit of work is quite significant for the purpose of measuring attention.

In copying, I had ten subjects, six graduate students in the first experiment; two graduate students and two senior college students in the last experiment, including one subject whom I had used before. In addition, I had nine subjects; four graduate students in the first experiment, three of whom were used in the second experiment, and four graduate students and one senior college student in the last experiment. All of these subjects were men. In learning, I had five graduate male students, two graduate female students, and three senior college female students. Besides these adult subjects, I was privileged to use some children of the William Lay School through the kind permission of Mr. John D. Shoop, Superintendent of schools in Chicago. Ninety-six children, namely, six boys and six girls from each grade took part in our experiments for three weeks. I am very grateful to these American boys and girls who served as my subjects, patiently and cheerfully, throughout the whole series of experiments which were carried on in the spring quarter of 1917.

CHAPTER II.

THE EFFICIENCY OF CONCENTRATED ATTENTION IN COPYING.

The first group of experiments concerns the relative efficiency of the two degrees of attention in copying a short series of nonsense syllables.

The general plan of constructing these syllables consisted of omitting the letter z and grouping the remaining twenty-five letters into five syllables of five letters each, rejecting all combinations obviously suggestive of meaning. Five such syllables constituted what we shall term a unit of work. Four hundred such units were constructed of such a character that no syllable was ever repeated. All units are thus highly similar. Each of the twenty-five letters appears but once in each unit. The units differed merely in the way the letters were combined.

Twenty of these units were typed on separate sheets of paper. The sheets of paper and the typewritten arrangement of the units were the same throughout. One such sheet of material constituted a day's work for a subject. The units of each sheet were divided into two equal parts. The upper half was copied with one degree of attention, while the lower half constituted the work for the other attentive attitude. The material of one of these sheets is given in Table 1.

The subject was furnished copy paper of a standard size and character. The copying was done with lead pencils and these were furnished of a standard degree of hardness. The attempt was made to keep these pencils uniformly sharp throughout the course of the experiment. The subject was allowed at the outset to arrange the two sheets of paper in reference to himself and to each other as desired, but any chosen arrangement was maintained for the rest of the experiment.

The experimenter gave a preparatory signal at the beginning of each unit of work. With normal attention the subject began copying at once. With excessive attention, a preliminary signal

TABLE 1. Specimen sheet of day's work.
Series 1 A. (For normal attention)

ewqkc	nspra	ohjld	ybmfu	txigv	fmhpe	jxayw	iborq	gudnk	vtlsc
mtxiy	hpjbg	aoveu	wrdfl	nqcks	vgflu	ixbds	cnyot	mjrkq	hwape
csknr	qawpe	hmjyo	lbufd	xtgvi	gatvs	udjni	rbqkh	yoxmw	lfcpe
lxrgi	fwbja	tcoqu	pmkdv	eyhns	pcmye	hnkof	sdwql	vuxrj	taigb
svuhd	yatnk	emqjg	ibopc	wrxfl	xwflr	bjagi	tnvdq	komcp	yhsue

Series 1 B (For excessive attention)

ruwxd	elycv	bpqat	njfso	gmhik	gnrbe	mtplu	fhqyw	ioacx	ksjvd
sihok	tvafm	gjqcd	xpynb	erlwu	rlqok	uyast	cwvxd	epfih	jbmgn
rlueb	pjngm	fiohq	aycwx	dvskt	idrlg	bvycw	tohxu	fmsep	qjank
qftbi	jmodv	asyrh	xceln	kpuwg	pkneu	ajsxw	gcmhq	lrofy	vtbdi
qjftm	nbsoa	ivekh	pxrdy	culwg	npeul	xcwkg	jrdvy	homsa	tfqbi

was given three seconds earlier to enable the subject to secure the given degree of concentration before beginning work. A short interval of a few seconds was allowed between successive units of work, while a minute intervened between the tests for the two degrees of attention. The subject was directed to secure the maximum of efficiency in speed or accuracy in every case. He was instructed to attempt to maintain the same degree of attention throughout any unit of work. In normal attention, the subject was directed to assume that attentive attitude which was most normal and customary in ordinary acts of work. In excessive attention he was instructed to work with additional voluntary effort, to assume the conscious attitude utilized in important and critical situations.

The efficiency of the work was measured in terms of speed or accuracy. The time required to copy each unit of work was measured with a stop watch. To this end the subject was instructed to give a tap with the pencil as soon as each unit was completed.

The various errors in the main belonged to one of the following classes,—omissions, insertions, transpositions, and substitutions. We attempted to work out a system of evaluating the different kind and degrees of error, but a study of the data convinced us that the kind of error was not influenced by the attentive attitude and hence such a scoring system was irrelevant to our purpose. All subjects frequently noticed errors as soon as made and corrected them. Other errors were unnoticed. Our tabular data gives the total number of errors made, those noted and corrected, and those which were unnoticed.

Experiment 1.

The first experiment consisted of two parts. In the first, twenty units constituted a day's work and the test was continued for six days. The first ten units of each day's task were performed with a normal attentive attitude, while extra effort was required for the last ten units. The subject was requested for both attentive attitudes to emphasize speed rather than accuracy. The relative efficiency of the two attentive attitudes in attaining speed must be measured in terms of time. These time records are given in table II. The values represent the number of seconds required for each individual to copy ten units. Each series refers to a single day's record. The A series gives the values secured for normal conditions, while series B contains the records secured for excessive attention.

The second part of the experiment duplicated all of the above conditions with the exception that the subjects were instructed to strive for accuracy. The proficiency for this work must be measured in terms of error. The records are given in table III. The first column gives the total number of errors which were noted and corrected. The second column gives the total number made which were not observed by the subject. The third column gives the total number of errors made irrespective of whether or not they were detected by the subject. In the fourth column is found the average number of errors made per day together with the mean variation.

TABLE II.

Record of Time When Attention Was Directed Toward Speed.

Data	Subjects.					
	E.C.	E.S.J.	C.L.K.	J.C.P.	C.R.	L.W.W.
Series IA	104	190	195	175	217	195
Series IIA	111	181	219	173	198	188
Series IIIA	114	192	207	169	200	186
Series IVA	105	171	190	177	201	180
Series VA	102	181	178	150	200	174
Series VIA	102	180	187	154	202	171
Av.	106.3	182.5	196	166	203	182
M. V.	4.1	5.7	11.3	9.7	4.6	7.3
Series IB	106	166	194	179	171	180
Series IIB	107	183	225	167	180	169
Series IIIB	110	166	195	173	185	195
Series IVB	103	170	184	162	183	182
Series VB	115	174	174	154	175	179
Series VIB	108	120	175	142	178	180
Av.	108	163	191	163	178.6	180.8
M.V.	2.8	14.5	13.5	10.2	4.0	5.1

TABLE III.

Record of Error When Attention Was Directed Toward Accuracy.

Subjects	Corrected errors	Uncorrected errors	Total	Daily Av.	M.V.
E. C.					
Normal	17	8	25	4.2	± .96
Excessive	17	3	20	3.3	±1.1
E. S. J.					
Normal	5	17	22	3.7	±1.7
Excessive	7	6	13	2.2	± .6
C. L. K.					
Normal	15	10	25	4.2	± .8
Excessive	10	7	17	3.4	±1.7
J. C. P.					
Normal	6	38	44	7.3	±1.9
Excessive	19	33	52	8.7	±2.3
C. R.					
Normal	5	7	12	2	± .67
Excessive	11	4	15	2.5	±1.17
L. W. W.					
Normal	10	13	23	3.8	±1.5
Excessive	17	19	36	6.0	±1.3

Experiment II.

The second experiment duplicated the conditions of the previous one with the following exceptions: work extended over a period of 10 days. An alternative order between normal and excessive attention was employed. On one day, normal attention was tested first and excessive attention last. This temporal order was then reversed for the subsequent day's work. This procedure eliminated any advantage which might accrue from the temporal order in which the tests were given. As before, the experiment contained two parts: one in which speed was emphasized and one in which the attention was directed toward accuracy. The results of the experiment are given in tables IV and V.

TABLE IV.

Record of Time When Attention Was Directed Toward Speed.

A Series stands for normal attention; B Series, for excessive attention.

Data	Subjects				
	M.	C.R.	R.L.	S.	T.
Series IA	139	239	134	149	172
Series IIA	141	205	125	154	160
Series IIIA	149	204	118	135	167
Series IVA	143	179	131	138	164
Series VA	134	188	138	140	149
Series VIA	141	197	137	136	164
Series VIIA	130	197	129	132	160
Series VIIIA	136	173	130	135	168
Series IXA	138	197	131	128	171
Series XA	122	170	125	129	156
Av.	137	195	130	138	163
M. V.	5.5	13.9	4.4	6.2	5.5
Series IB	125	200	115	137	156
Series IIB	131	183	104	142	151
Series IIIB	141	187	98	137	144
Series IVB	124	167	117	129	150
Series VB	137	180	111	128	150
Series VIB	131	172	106	133	144
Series VIIB	131	148	110	124	154
Series VIIIB	123	166	111	125	154
Series IXB	145	167	112	124	147
Series XB	105	171	103	130	147
Av.	129	174	109	131	150
M. V.	8.1	10.7	4.7	5.1	3.3

Conclusions.

1. *Effort and Speed.* Extra attentive effort was effective in increasing the speed for but two subjects, E.S.J., and C.R., in the first test. The differences in speed for the other four subjects were not large enough to be significant. (See table II.) In the second test concentration was effective in increasing speed for but two of the five subjects, C.R. and T. It is to be noted that the subject C.R. gave identical results for the two conditions.

These facts indicate that any efficiency of concentration in at-

TABLE V.

Record of Error When Attention Was Directed Toward Accuracy.

Subjects	Corrected errors	Uncorrected errors	Total	Daily Av.	M.V.
M.					
Normal	20	12	32	3.2	± .88
Excessive	18	11	29	2.9	±1.58
C. R.					
Normal	8	2	10	1.0	± .8
Excessive	6	2	8	.8	± .8
R. L.					
Normal	28	17	45	4.5	±1.6
Excessive	20	4	24	2.4	±1.5
S.					
Normal	18	7	25	2.5	±1.0
Excessive	15	10	25	2.5	±1.2
T.					
Normal	16	5	21	2.1	±1.1
Excessive	18	9	27	2.7	±1.04

taining speed is limited to certain individuals, and that the comparative records as to the efficiency of the two attitudes is not influenced by the temporal order of the tests.

2. *Effort and Accuracy.* Extra attentive effort was not effective in preventing error. This fact is apparent from an inspection of the records of total error in tables III and V. No uniformity is present. In only two cases, L.W.W. and R.L. are the differences sufficiently large to approximate any degree of significance.

Neither did the extra attentive effort aid in the detection and correction of error. In no case are the differences sufficient to be significant. The ratio of errors noted for the two attentive attitudes is practically the same as the ratio of the total number made for those two conditions in eight of the eleven cases of comparison. Apparently the relative number of errors detected is primarily a function of the total made and not due to a difference of attentive attitude.

3. *Speed and Accuracy.* The attempt to increase speed as compared with that attained when the maximum of accuracy was demanded was successful with all subjects. The comparative records are given in Table VI.

TABLE VI.

Subjects	When attention was directed toward accuracy	When attention was directed toward speed	Percentage of increase
E.C.			
Normal	131	106.3	19%
Excessive	136.3	108	20%
E.S.J.			
Normal	190.5	180.5	5%
Excessive	213.5	163	24%
C.L.K.			
Normal	247.2	196	20%
Excessive	242	191	21%
J.C.P.			
Normal	203.3	166	19%
Excessive	200	163	19%
C.R.			
Normal	249	203	18%
Excessive	312	178.6	43%
L.W.W.			
Normal	249.5	182	27%
Excessive	238	180.8	24%
M.			
Normal	169	137	19%
Excessive	165	129	22%
C.R.			
Normal	207	195	6%
Excessive	259	174	33%
R.L.			
Normal	152	130	15%
Excessive	170	119	30%
S.			
Normal	164	138	16%
Excessive	168	131	22%
T.			
Normal	223	163	27%
Excessive	193	150	33%

The table indicates that the greatest increase was manifested by C.R. who secured 43% for excessive attention. The five subjects E.S.J., C.R., M., R.L., S., and T. secured the greater increase in speed on the part of their excessive attention, while L.W.W. is the only subject who obtained the opposite result. E.C., C.L.K., and J.C.P. showed no difference in the percentages of increase for the normal and the excessive. The average percentages of increase for all subjects are 17% for normal and 26% for excessive attention.

The attempt to decrease the total number of errors made relative to the accuracy attained when speed was demanded was successful with ten subjects. E.S.J. was the exception. The attempt to achieve accuracy rather than speed diminished the total number of uncorrected errors with the exception of E.S.J. The emphasis on accuracy, however, did not influence the total number of errors noted and corrected. Six subjects made slightly more corrections and gave a poorer record when accuracy was requested. The number of corrections relative to the total number made (percentage of corrected errors) was increased with the exception of two individuals. The comparative records are given in table VII.

TABLE VII.

Subjects	Total errors when attention was directed to accuracy	Total errors when attention was directed to speed	No. of uncorrected errors in accuracy	No. of uncorrected errors in speed	Percentage of corrected errors in accuracy	Percentage of corrected errors in speed
E.C.	45	55	11	28	75	47
E.S.J.	35	33	13	15	34	54
C.L.K.	42	60	17	42	60	30
J.C.P.	96	101	71	83	26	17
C.R.	27	61	11	38	60	38
L.W.W.	59	78	32	60	46	23
M.	61	80	23	27	62	66
C.R.	18	54	4	30	77	44
R.L.	69	236	21	213	70	10
S.	50	70	17	43	66	38
T.	48	152	14	116	70	23

In the act of copying, speed and accuracy are generally antagonistic when either aspect is emphasized beyond the normal. Speed may be voluntarily increased but this additional efficiency is attained by a sacrifice of accuracy. Accuracy may also be increased, but at the expense of speed. This antagonism obtained for 10 subjects. E.S.J. was able to increase speed with no loss of accuracy, or the attempt to secure greater accuracy was unsuccessful even though speed was decreased.

Speed and accuracy are independent variables however, in comparing individuals. The fastest copiers may be either the most or the least accurate of the group. Correlation values between speed and accuracy were computed by the rank method and in all six cases of comparison small positive or negative values were secured. There was no correlation between speed and accuracy measured in terms of total error, uncorrected error, or ability to detect error stated in either absolute or relative terms. The closest approximation to a valid relation was between speed and critical ability when accuracy was demanded.

4. *Individual Differences.* There are pronounced individual differences in the rate of copying when either speed or accuracy is demanded. There are also individual differences as to uniformity of speed from day to day. The mean variations representing the range of daily fluctuations are not a function of the rate. For example, E.C. is extremely fast and consistent, C.L.K. is slow but highly erratic, while C.R. is slow and consistent.

There are probably individual differences in the ability to copy accurately when either speed or accuracy is demanded. These differences of accuracy are not a resultant of differences of rate as no correlation obtains between speed and accuracy.

There is some indication of individual differences in the ability to detect errors made. When accuracy is demanded the number of errors noted is to a large extent a function of the total made. The correlation between the two is $+.77$. The individual differences in critical ability are thus largely a function of accuracy. When speed is demanded, there is no significant relation between errors noted and the number made. Stated in percentage terms, there are quite wide differences in the ability to note error. There is some possibility that the capacity to note error measured in percentage terms is related to the rate of copying when accuracy is emphasized.

CHAPTER III.

FLUCTUATIONS OF EFFICIENCY DURING SHORT PERIODS OF WORK.

In the experiments described in the previous chapter, subjects were required for each day's sitting to copy ten units of work in rapid succession under constant attentive conditions. Time records were taken separately for each unit. We are thus able to compare the efficiency of the work from unit to unit. On the basis of these data we propose a discussion of such temporal fluctuations of efficiency occurring in a relatively brief period of work devoted to copying nonsense syllables. For purposes of convenience we shall discuss fluctuations of speed and accuracy separately.

Fluctuations of Speed.

The data are presented in table VIII. The terms "first" and "last" in the table are the average time in seconds required in copying each of those units in a day's work. The "intermediate" values represent the average of the eight units of work between the first and the last. All the time values for the subjects belonging to group A represent an average for six days. The first and the last are thus based on an average of six units of work, while the intermediate represents the average of 48 units of work. Group B continued the work for ten days and their values represent an average of ten measurements. The first and the last terms give the average of ten units of work and the intermediate represents an average of 80 units of work.

The phenomenon of the initial spurt in the speed of copying was manifested in some degree by all subjects for both attentive attitudes. The term "initial spurt" refers to the fact that on the average the first unit for each day's work was copied more quickly than the subsequent ones.

The final spurt was manifested for both attentive attitudes by

TABLE VIII.

Fluctuations of Speed in Copying.

	Group A.				Group B.		
Subjects	First	Intermediate	Last	Subject	First	Intermediate	Last
E.C.				M.			
Normal	10.5	10.6	10.1	Normal	12.5	14	13
Excess.	10.5	10.7	11	Excess.	11.5	13.2	12.5
E.S.J.				C.R.			
Normal	17.5	18.5	17.1	Normal	17.5	19.7	19.3
Excess.	15.3	17.2	16.8	Excess.	16.2	17.6	17
C.L.K.				R.L.			
Normal	19	19.6	20	Normal	12.7	13.1	12.3
Excess.	16.8	19.4	19.8	Excess.	10	11.1	9.9
J.C.P.				S.			
Normal	16	16.7	15.8	Normal	13.7	15	14.1
Excess.	15	16.4	16	Excess.	12.4	13.2	13
C.R.				T.			
Normal	19	20.4	20.3	Normal	14.3	16.5	16.7
Excess.	16	18.1	17.6	Excess.	13.5	15.1	15.5
L.W.W.				Av. Normal	14.1	15.7	15.1
Normal	15	18.8	18				
Excess.	14.5	18.5	18	Av. Excess.	12.7	14	13.6
Av. Normal	16.1	17.4	16.9				
Av. Excess.	14.7	16.7	16.5				

nine of the eleven subjects. This term refers to the fact that the speed of the act was quickened as the last unit of each day's work was reached.

An analysis of the records for the intermediate units reveals the fact that no uniform fluctuation of speed occurred during the period.

The comparative data for the two attentive attitudes shows that the extra attentive effort was successful in increasing speed for all periods of the day's work, for eight of the eleven subjects. The initial spurt was manifested in a relatively greater degree for the excessive attentive attitude in nine of the eleven subjects, while the normal attitude was the more effective in promoting the final spurt in eight subjects. These facts indicate that while extra effort tends to be effective throughout each day's task, yet its greater efficiency is manifested in the initial units.

There is no unanimity among writers as to the existence of the initial and final spurts. Thorndike denies the existence of both phenomena, saying:[1] "I am unable to find anywhere any evidence of a consistent initial spurt with any individual in all mental functions or with all (or nearly all) individuals in any kind of mental work." This statement seeems to be questionable, and so far as the writer sees, the phenomenon of the initial spurt may depend more or less on the kind of mental work, the duration of time and the different type of individual habits of work.

Fluctuations of Accuracy.

The previous mode of procedure was utilized in studying the temporal fluctuations of accuracy during a short period of work. Errors were recorded for each unit separately. The average error records were computed for the first, last, and the eight intermediate units of each day's work. Comparisons as to the accuracy are much more difficult than for speed because of the greater variability in the error records.

The existence of both the initial and the final spurt is indicated by the results. The average records for the two groups are given in table IX. The initial and final spurts are evident for both groups and for both attentive attitudes. The individual records are not given. However, the initial spurt was present for five of the six subjects of group A and for four of the five in group B. The final spurt was manifested by seven of the eleven subjects.

Any extra attentive effort is not uniformly successful in achieving accuracy throughout the day's work. The better average results for both groups were obtained by the excessive attitude only for the initial and intermediate periods of work. In other words, the efficiency of extra effort in achieving accuracy is confined to the initial stages of a brief period of work.

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[1] "Educational Psychology," Vol. III. p. 55.

TABLE IX.

	first	intermediate	last
Group A.			
Average of Normal	.33	.47	.33
" " Excess.	.30	.39	.38
Group B.			
Average of Normal	.24	.28	.20
" " Excess.	.16	.23	.22

Conclusions.

In the act of copying the existence of an initial and final spurt in efficiency is indicated by both the speed and error records. The initial spurt is the more pronounced.

There is no evidence of any uniform temporal fluctuations during the intermediate periods.

The efficiency of any extra attentive effort in achieving either speed or accuracy is most pronounced in the initial stages of each day's work, and this initial greater efficiency tends to decrease with the duration of the task.

CHAPTER IV.

THE EFFICIENCY OF CONCENTRATED ATTENTION IN ADDITION.

This chapter attempts a comparison of the relative efficiency of the two degrees of attention in the task of adding columns of one-place numbers.

The following scheme was adopted in order to construct a number of standard units of work of comparable difficulty. Two such units are given in table X. Each unit consists of ten columns of ten one-place numbers so chosen that the sum of each column lies between 45 and 50 while the total sum of each

TABLE X.

Specimen Units of Work.

A

6	5	4	2	7	7	6	4	5	9
7	6	5	9	8	6	8	2	6	8
8	7	6	8	1	3	4	7	3	6
1	8	7	1	6	4	9	1	9	3
5	4	5	5	7	2	1	6	7	5
2	5	4	4	9	1	2	7	2	1
7	2	5	5	2	3	5	3	8	6
4	6	7	2	3	8	7	2	3	3
2	3	2	6	5	9	2	9	5	2
3	2	1	5	1	2	3	5	1	7
45	48	46	47	49	45	47	46	49	50

B

6	6	7	1	4	5	5	3	6	2
4	8	2	6	7	6	8	5	3	9
9	3	7	4	1	8	7	4	5	7
7	2	1	9	8	2	9	8	4	2
6	9	9	8	9	9	2	9	9	5
1	1	6	2	2	1	1	1	2	7
4	4	2	4	6	6	3	4	1	6
5	5	5	7	1	3	4	7	5	2
3	3	3	5	5	6	6	2	2	4
1	8	4	2	4	4	1	5	8	3
46	49	46	48	47	50	46	48	45	47

Sum of A = 472 Sum of B = 472 Sum of A = Sum of B.

TABLE XI.

Record of Time and Error, With Normal Attention (upper table) and Excessive Attention (lower table) to Accuracy.

	E.S.J.		C.L.K.		L.W.W.		K.	
	Time	Error	Time	Error	Time	Error	Time	Error
Series IA	397	3	330	4	460	5	494	3
Series IIA	390	2	342	2	412	6	488	4
Series IIIA	392	0	311	2	375	8	423	5
Series IVA	370	2	314	2	374	4	414	5
Series VA	385	0	308	1	381	8	429	4
Series VIA	331	3	288	2	389	3	418	6
Av.	377.5	1.7	315.5	2.17	398.5	5.67	444	4.5
M.V.	18		13.7		25		31	
Series IB	512	3	310	4	450	8	379	6
Series IIB	394	0	322	1	391	8	408	5
Series IIIB	423	2	291	3	350	9	382	8
Series IVB	383	3	295	1	348	5	399	4
Series VB	395	1	287	3	341	3	416	5
Series VIB	377	1	287	3	345	3	385	2
Av.	414	1.7	298.7	2.5	370.8	6	394.8	5
M. V.	36		11.6		33.1		12.8	

TABLE XII.

Record of Time and Error, With Normal Attention (upper) and Excessive Attention (lower) to Speed.

Subjects.

	E.S.J.		C.L.K.		L.W.W.		K.	
	Time	Error	Time	Error	Time	Error	Time	Error
Series VIIA	342	2	297	4	...	..	395	4
Series VIIIA	340	1	288	2	312	4	442	2
Series IXA	329	2	280	2	318	6	429	2
Series XA	322	3	271	0	292	2	402	3
Series XIA	320	3	268	1	345	5	397	4
Series XIIA	348	2	268	4	314	3	402	5
Av.	33.5	2.7	278.7	2.17	316.2	4	411	3.3
M. V.	10		9.7		12.2		16	
Series VIIB	335	5	264	6	...	..	370	2
Series VIIIB	315	5	281	2	347	4	417	7
Series IXB	303	3	262	3	322	3	385	5
Series XB	309	2	264	2	299	4	418	6
Series XIB	345	3	253	0	319	2	360	2
Series XIIB	314	3	265	0	322	4	397	3
Av.	320.2	3.5	264.8	2.17	322	3.4	391	4.2
M. V.	13.2		5.4		10.2		19.5	

unit is invariably 472. Some fifty of these units were constructed of such a character that no unit or column was employed twice. Two such units were typed on sheets of paper, and presented visually to the subject.

Each column was added separately and the sum recorded. The work was continuous throughout a unit, the subject beginning a second column immediately after recording the sum for the first. In these experiments the test for normal attention was invariably given first for each day's work. An interval of a minute was then allowed before beginning the test for excessive attention.

The efficiency of the work was measured in terms of speed or accuracy. The time required to complete each unit of work was recorded with a stop watch. The accuracy of the units was measured in terms of the number of columns added correctly. Thus the greatest possible number of errors per unit was ten. No attempt was made to evaluate the different degrees of error in adding a single column. A wrong total was counted as one

TABLE XIII.

Record of Time and Error, With Normal Attention (upper) and Excessive Attention (lower) to Accuracy.

	Subjects.					
	E.S.J.		C.L.K.		L.W.W.	
	Time	Error	Time	Error	Time	Error
Series IA	150	0	175	0	153	3
Series IIA	140	0	143	1	147	1
Series IIIA	164	1	148	3	152	1
Series IVA	165	0	156	0	172	1
Series VA	134	1	155	3	174	0
Series VIA	161	2	154	0	187	4
Av.	152.3	.67	155	1.17	164	1.67
M.V.	11		6.8		13.5	
Series IB	144	1	159	0	150	2
Series IIB	151	1	153	0	167	1
Series IIIB	185	2	143	0	156	4
Series IVB	179	2	170	2	161	3
Series VB	159	1	155	1	168	3
Series VIB	168	3	162	2	173	3
Av.	164.3	1.67	157	.83	162.5	2.67
M.V.	13		6.7		6.8	

error, no matter whether the recorded sum deviated from the true result by two or eleven.

The experimental conditions were varied somewhat during the progress of the experiment. 1. A day's work consisted of four units with normal attention followed by four units with excessive attention. In both cases the attention was directed toward the attainment of the maximum of accuracy. This procedure was continued for six days. These results are to be found in table XI. In these as in the subsequent tables, the term 'Series' refers to a day's work for a given attentive attitude. Those series marked A refer to the results achieved with normal

TABLE XIV.

Subjects.

Record of Time and Error, With Normal Attention (upper) and Excessive Attention (lower) to Accuracy.

	C.R.		J.C.P.		S.		Rl.		T.	
Data	Time	Errors	Time	Errors	Time	Errors	Time	Errors	Time	Errors
Series IA	59	0	96	4	73	0	59	1	93	0
Series IIA	76	1	99	3	73	2	67	1	93	4
Series IIIA	72	2	106	3	73	0	70	0	97	2
Series IVA	60	0	94	2	74	1	58	1	96	1
Series VA	57	1	97	0	70	1	75	0	86	3
Series VIA	56	0	99	1	68	1	55	0	88	5
Series VIIA	59	0	87	3	67	1	55	0	80	0
Series VIIIA	57	0	89	2	67	0	58	2	90	0
Series IXA	78	0	92	3	70	0	60	0	102	1
Series XA	79	0	94	1	70	0	63	0	85	1
Av.	65	.4	95	2.2	70.5	.6	62	.5	91	1.7
M.V.	8.7		4.1		2.2		5.4		5.2	
Series IB	74	1	105	3	75	2	60	1	92	0
Series IIB	82	1	104	0	77	1	60	0	95	0
Series IIIB	83	0	97	1	82	1	55	0	83	0
Series IVB	85	0	104	2	78	0	70	0	85	2
Series VB	82	0	108	2	72	0	72	0	83	2
Series VIB	78	0	102	2	77	0	54	0	82	1
Series VIIB	85	0	108	0	66	0	75	0	76	0
Series VIIIB	83	0	98	0	78	0	46	0	99	1
Series IXB	91	0	87	1	73	0	48	2	77	2
Series XB	77	0	92	2	78	0	60	0	81	3
Av.	82	.2	100	1.3	76	.4	60	.3	85	1.1
M.V.	3.4		5.7		3.2		7.4		5.9	

attention, while B denotes the employment of excessive attention. 2. The above procedure was now repeated with the exception that the attention was directed toward speed instead of accuracy. The results obtained are given in table XII. 3. The first procedure was duplicated except that but two units for each degree of attention constituted a day's work. These results are to be found in table XIII. 4. The third procedure was continued except that but one unit per day was given for each attentive attitude and the work was continued for ten days. The data from this test are given in table XIV.

The above variations of procedure thus consisted of altering the duration of a day's work, and the number of days over which the experiment was continued.

Conclusions

1. *Effort and Accuracy.* The results of extra attentive effort in securing accuracy in arithmetical computations are given in the comparative error records of tables XI, XII, XIII, and XIV. In table XI, effort increased the error record with three subjects and was without influence in one case. The differences are not sufficiently large to be significant. In table XIII, effort increased the error records in two cases and decreased it in the third. None of the differences are probably significant. In table XIV, effort decreased the number of errors with all five subjects. The differences in at least three cases are not significant. The fact that uniform results were obtained for all subjects indicate a possible influence of effort in decreasing error in this test.

We thus conclude that effort is not effective in securing greater accuracy in numerical computations with the possible exception for the shorter periods of work, two units per day. This possible exception indicates that the efficiency of additional attentive effort directed towards securing accuracy may be dependent upon the duration of the work and possibly upon the individual.

2. *Effort and Speed.* The extra attentive effort in securing speed decreased the average time values for three subjects and increased it for one subject. The differences are not sufficiently

great to be significant with the possible exception of one subject, (C.L.K. table XII). We conclude that effort is not effective in securing speed in arithmetical computations.

3. *Relation of Speed and Accuracy.* Any attempt, both normal and excessive, to secure the maximum of accuracy was unsuccessful. On the contrary, the error records of table XI when accuracy was emphasized are larger than when speed was emphasized, (table XII) in five out of eight comparisons. However, the differences are probably not large enough to be significant. The unsuccessful attempt to secure a greater amount of accuracy resulted in a diminution of speed for all subjects. The differential results are significant for three of the four subjects. These time differences may be due in part to practice.

Stated in opposite terms most attempts to secure speed are successful without any loss of accuracy, but the attempt to secure accuracy is unsuccessful even though speed is sacrificed. The maximum amount of all-around efficiency in numerical computations is thus secured by emphasizing speed rather than accuracy.

4. *Individual Differences.* There are some individual differences in both speed and accuracy which are large enough to be significant. The differences are largest in table XI and smallest in table XIII, which fact indicates that the individual differences tend to disappear with practice. Individual differences are again apparent in table XIV when a new group of subjects was employed

There is no necessary antagonism between speed and accuracy in comparing individuals. Subjects L.W.W. and K. are comparatively slow and inaccurate (XI-XIII). The same statement is applicable to J.C.P. and T. in table XIV. However, there is no exact correlation between speed and accuracy. C.R. is the most accurate of his group but not the fastest. C.L.K. is speedier than E.S.J. but is not consistently the more accurate of the two.

The individual differences as to variability in time are to some extent a function of the absolute time values. The largest m.vs. are associated with the largest average time values in six of eight comparisons. The least m.vs. are associated with the smallest averages in five of eight comparisons. There are probably some individual differences in consistency.

5. *Efficiency and length of task.* The speed of adding is a function of the length of the daily task when the maximum of accuracy is demanded. The shorter the task, the greater is the speed with which it is performed. The average times in seconds required by an individual to add a unit of work were 94.2, 79.6, and 78.6 when the daily work consisted of 8, 4 and 2 units respectively. These values are based upon the records of tables XI, XIII, and XIV. The differences between these values can not be due to practice as both groups in the first and third tests were unpracticed, and the first group completed more than twice the work done by the second group. Practice may have contributed in part to the low values in the second test, but the initial speed in this test was much faster than the final speed of the first test.

There is no evidence that the number of errors per unit depends upon the length of the day's task. The average number of errors per unit were .91, .72, and .87 when the daily task consisted of 8, 4 and 2 units. The low values of the second test may be due in part to practice and in large part to the fact that the poorest subject in the first test did not continue his work in the second test. Eliminating the record of this individual, the two values are .81 and .72.

The greater speed for a short task can be explained on the same basis as the phenomenon of the final spurt. When the task is long, the subject conserves his energy and goes slow. With a short task, on the contrary, the subject tends to work with the maximum of speed.

6. *Practice Effects.* In the first test (table XI) all subjects increased their speed during the six day's work. Comparing the records for the first and the last halves of the test, the time values were decreased by about 10% on the average. A further improvement by those subjects during the second test (table XII) was not so evident, while no improvement was manifested during the third test by those subjects who continued the experiment.

The record of this group indicates that practice is quite effective in increasing the speed of adding, but that this effect is limited to the first six days, when eight units constitutes a day's task. Improvement in speed was also manifested by the second group (table XIV). Comparing the records for the first and last halves of the test, four of the five subjects increased their speed by 4% to 5%. The smaller improvement of this group may be due in part to the lesser amount of work, for this test utilized but 20 units as compared with 48 for the first group.

No assertions as to improvement in accuracy can be made for the individuals owing to the high degree of variability in their error records. Taking the records for the group as a whole and making comparisons as formerly, similar results are obtained. The first group decreased their error record by 30% during the first test, by 12% during the second test, but manifested no further improvement during the third test. The second group also manifested considerable initial improvement. It is probable that considerable initial improvement in both speed and accuracy may result from practice.

CHAPTER V.

THE EFFICIENCY OF CONCENTRATED ATTENTION IN MEMORIZING.

The third group of experiments proposes to determine the relative efficiency of the two attentive attitudes in memorizing. Educational theory has assumed that the speed and efficiency of learning is directly proportional to the degree to which the mind is concentrated on the task at hand. The ability to develop and maintain a high degree of mental concentration has been regarded as one of the essential characteristics of an ideal student. This popular belief is illustrated by the following quotation from Meumann:[1]

> "A first point which concerns us in learning is the regulation of attention. The attributes of attention which have chiefly to do with learning and retention are intensity and uniformity of concentration throughout the whole act of learning, and particularly persistence of attention throughout. . . . The more intensively a person concentrates his attention upon his act of learning, the sooner will he succeed, as a rule, in memorizing."

We utilized the method of paired associates. Five pairs constituted a unit of work. The following kinds of material were constructed and utilized in the tests: 1. In twenty units, the first or stimulus term consisted of two letters,—a consonant and a vowel. The second or response term was an arbitrary symbol constructed of three short straight lines. No term appeared twice in the twenty units. 2. The stimulus term was a word of four letters, while the associate to be recalled was an arbitrary symbol composed of four straight lines. One half of the words were concrete and the other half abstract. Ten units were used and no word or symbol occurred twice. 3. The stimulus term was an ordinary nonsense syllable of three letters, while the second term was an arbitrary symbol of four straight lines. Ten units were constructed in which no term was used twice.

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[1] "The Psychology of Learning," p. 279.

Illustrative specimens of these three types of material are given in fig. 1.

For subjects we employed a group of ten adults, all of whom were either graduate or senior college students. In addition we tested a group of twelve children from each of the eight grades of the William Lay School. For our conditions the material proved too difficult for the first four grades; the amount reproduced was so small that comparisons as to the relative efficiency of the two attentive attitudes were valueless. Our tables thus give the comparative data only for the fifth to the eighth grades inclusive. These children were selected by the teacher in charge from those who volunteered their services.

We presented the materials to the adult group by means of a tachistoscope projection apparatus in which the pairs were projected on an illuminated ground glass screen. The pairs of each unit are exposed in rapid succession, the time of exposure for each pair being three seconds. Each unit was presented but once, and the amount memorized was tested by an immediate graphical reproduction. In the reproductive test, the stimulus terms were presented as before. Each subject of this group was tested separately.

For the groups of children, each pair was printed on a card in large bold-faced characters. The stimulus term of each pair was printed on the back of each card. The children were tested in groups. The experimenter arranged the cards in bunches of five. Each bunch was placed against a screen on the desk. The front or visible card was allowed to fall after the proper exposure, the five pairs thus being exposed in succession. The pairs were presented in immediate succession, each card being visible for three seconds. Each unit was presented but once, and the amount memorized was tested by immediate graphical reproduction. For the reproductive series the cards were rearranged, and the backs of the cards on which the stimulus terms were printed were exposed as before.

The following system of scoring was adopted in order to measure the amount reproduced. 20% was allowed for a perfect reproduction of each of the five symbols constituting a

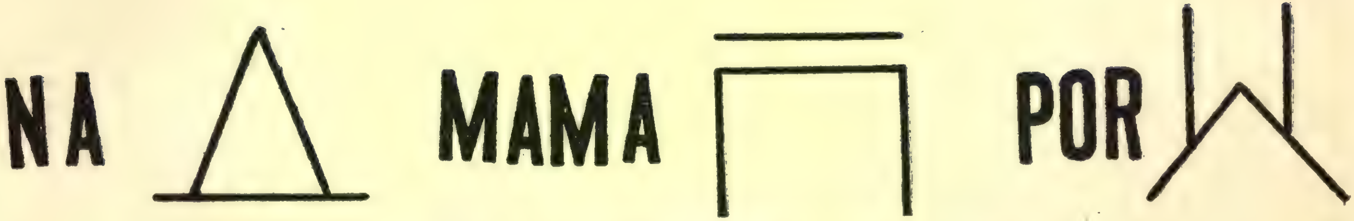

Fig. 1. Specimens of three types of memory material.

unit. 10% was allowed if a symbol was reproduced with the wrong associate. A symbol reproduced upside down was scored 10%. 10% was deducted when one of the lines of the symbol was drawn incorrectly. 5% was deducted when any line was either over or under drawn.

Two main experiments were performed. 1. The first concerned the relative efficiency of the two attentive attitudes. The first type of material was employed. Two units were given each day: the first was studied during one exposure with a normal attentive attitude, and the amount learned was tested by graphical reproduction. After a two-minute interval a second unit was employed for excessive attention. This procedure was continued for ten days. For the first five days the reproductive order of the pairs was the same as that of their first presentation. In the second half of the experiment, the order of the pairs in the reproductive series was different from that of their presentation. 2. In the second experiment we tested the value of meaning as a suggestive or stimulus term, when the term to be recalled is meaningless. For the purpose we utilized the second and third types of material. In both types, the second or reproduced term is an arbitrary symbol composed of four straight lines. The two types differ only in the first or cue-word; in one it is a nonsense syllable and in the other, a word. Comparisons of the amount reproduced in each case will determine whether or not a meaningful stimulus cue is more suggestive than a meaningless one. Two units per day were given, first one of type 2, and then one of type 3. Each was presented once and studied with the excessive attentive attitude. The amount learned was tested immediately. The reproductive order of the pairs was different from the order in which they were presented. The test was continued for ten days. For the first five days the meaningful cue-word was concrete, while in the latter half of the test, the cue-word was abstract.

Conclusions.

1. Normal and excessive attention did not differ in effectiveness for the adult group. The average percentages of reproduction for normal and excessive attention were 81.6 and 82.3 respectively. Eight of the ten subjects gave slightly better records for the effortful attitude, but the differences are too small relative to the daily variations to be significant. No subject manifested any pronounced daily consistency in preferring one of the two attitudes. One individual gave the better record for the normal attitude for seven of the ten days while another individual gave a like preference for the excessive attitude.

2. There is some indication that normal attention is more effective with children. The average percentages of reproduction for the four grades are given in table XV. The normal attitude gave the better results for all grades.

TABLE XV.

The Average Percentages of Reproduction in Children.

	8th grade group	7th grade group	6th grade group	5th grade group
Normal	60.65	53.04	48	38
Excessive	58.88	45.3	41	32.5
Difference	1.77	7.74	7	5.5

Thirty-five of the forty-eight subjects gave a better average reproduction score for the normal attitude. When we examine the individual records we find that for the majority of subjects the average scores for the two attitudes are not sufficiently different relative to the high mean variability so that any assertions can be made as to the relative efficiency of the two conditions. Neither do most individuals exhibit any consistency from day to day in making a larger score for one attitude. Of the total group of forty-eight subjects, we give in table XVI the list of those whose records give the most indication of the influence of the attentive factor. This table gives for the two attentive attitudes, the daily percentages of reproduction, the average percentage score and the mean variation. One subject gives the best record for excessive attention, and eight for the normal attitude. All exhibit some degree of daily consistency.

TABLE XVI.

N stands for Normal Attention, E for Excessive Attention. Absences are Indicated by Blank Lines.

	1	2	3	4	5	6	7	8	9	10	A.V.	M.V.
C.M.												
N.	50	20	55	75	40	30	35	35	20	40	40	12
E.	50	20	40	30	30	35	30	30	0	35	30	8
A.B.												
N.	25	30	20	25	80	30	50	50	30	20	36	14.4
E.	35	30	0	35	30	20	20	40	0	15	22.5	11.5
G.K.												
N.	20	35	60	30	40	20	..	..	..	..	34	10.8
E.	15	10	0	40	30	10	..	..	..	..	17.5	11.6
C.W.												
N.	50	45	60	75	55	100	40	80	..	40	60.5	15.7
E.	55	30	40	60	50	20	60	60	..	10	43	15.8
S.C.												
N.	60	60	45	75	60	70	60	45	20	55	55	11
E.	55	40	35	80	60	35	30	30	30	30	42.5	13.5
F.E.D.												
N.	65	30	..	80	..	60	40	..	40	40	50.7	15.1
E.	35	30	..	30	..	10	35	..	45	40	32	7.6
D.R.												
N.	40	60	30	70	60	..	..	..	..	..	52	13.6
E.	25	30	10	35	60	..	..	..	..	..	32	12.4
M.J.												
N.	60	60	65	90	90	70	50	..	..	..	69.3	12
E.	60	50	65	70	70	60	50	..	..	..	60.7	6.5
D.P.												
N.	60	50	50	70	..	..	..	40	50	40	51.4	7.7
E.	80	60	65	80	..	..	..	60	50	50	63.5	9.7

3. In the grades, the girls gave better average records than the boys for both attentive attitudes. There was no sex difference in the adult group. The number of the two sexes were equal for all five groups. The comparative records are given in table XVII.

TABLE XVII.

The Average Percentages of Reproduction for Both Sexes.

			8th grade		7th grade		6th grade		5th grade	
Sexes	Men	Women	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Normal	81.5	81.5	59.5	61.5	50.6	51.5	43.5	52	36.8	39.8
Excessive	83	83	57	60.5	41.5	49	41	52.5	32.2	33.3

4. The irregular order of reproduction tends to decrease the

efficiency of reproduction as compared with the regular order of exposure. The fifth grade group is the only exception to this rule, for it shows no difference for the two procedures. Table XVIII gives the average percentages of reproduction for both the regular and the irregular exposure. There is no evidence that the disconcerting effect of irregular exposure varies with age.

TABLE XVIII.

The Relative Efficiency of Regular and Irregular Presentation

	Normal		Excessive	
Subjects	Regular	Irregular	Regular	Irregular
Adults	82.5	80.7	85.7	80.7
8th grade	62.6	58.7	60.75	57
7th grade	57.75	48.3	47.9	42.7
6th grade	55	41	52.5	40
5th grade	38	38	32	33

5. The effect of meaning upon the memorizing process is clearly brought out by the second part of the experiments in this chapter. Learning artificially constructed characters by meaningful association is decidedly favorable over against learning them by nonsense syllables. There is no evidence that the value of meaning either increases or decreases with age in any regular fashion. The average percentages of reproduction for the meaning and nonsense series are found in table XIX.

TABLE XIX.

The Influence of Meaning in the Memorizing Process.

	Meaning	Nonsense
Adults	80.7	65.45
8th grade group	52.87	41.87
7th grade group	50.45	32.85
6th grade group	36.12	23.5
5th grade group	25.62	18.75

6. In the meaning series, concrete words are more effective in reproduction than abstract ones. This fact is observed for both adults and children. There is some indication that the relative efficiency of concrete words becomes less with age. Table XX gives the average percentages of reproduction for concrete and abstract words.

TABLE XX.

The Relative Effect of Concrete and Abstract Words in Memorizing Process.

	Concrete	Abstract
Adults	87.9	73.5
8th grade group	54	51.75
7th grade group	59	41.9
6th grade group	45.25	27
5th grade group	30.75	20.5

7. Memory grows with age for all materials. Tables XVIII, XIX, and XX show that the memorizing process is a gradual development. Take, for instance, the meaning series of table XIX, the average percentage of reproduction of adults is 80.7; that of the 8th grade group is 52.87; that of the 7th grade group is 50.45; that of the 6th grade group is 36.12; and finally, that of the 5th grade group, 25.62. Thus the average percentage of reproduction becomes smaller and smaller as the grade becomes lower.

CHAPTER VI.

SUMMARY AND GENERAL CONCLUSIONS.

1. *Attentive Effort and Efficiency.* Educational theory has frequently assumed that the efficiency of work can be materially stimulated by the teacher by the demand for extra attentive effort on the part of the students. Teachers are prone to demand that students pay extra attention to their tasks, to work with effort or a high degree of mental tension. Mature students likewise assume that they can increase their efficiency by voluntary effort, by an attitude of mental tension, or in popular language, by voluntarily concentrating their attention on the task at hand.

It has been our purpose to test the validity of this assumption in three types of activity. Subjects were requested to perform tasks of equal difficulty with two different mental attitudes, their customary or usual attitude, and one representing a high degree of mental effort and attention.

In copying, effort increased speed with certain individuals, and the maximum of effect was secured in the initial stages of each day's work. There was no conclusive evidence that effort operated to decrease the number of errors or to aid in their detection. There was some indication that effort might be effective in preventing errors in the initial stages of each day's task.

In addition, effort failed to increase speed with the possible exception of one subject. It operated to increase accuracy for some subjects when the day's work was quite short. This fact tends to confirm the conclusion concerning copying,—that the efficiency of effort was confined mainly to the initial stages of each day's work.

In memory, effort was without effect for adult subjects, and it was possibly detrimental for some of the children.

The effect of any extra mental effort voluntarily aroused or stimulated by the experimenter is a function of the individual, his age or experience, and the kind of work and its duration.

The results thus disprove the assumption in the main. Voluntary effort made under conditions such as these in this experiment (comparable with many situations in school and industrial life) may be slightly stimulating in limited circumstances, but it is doubtful if the extra efficiency attained will compensate for the additional energy and strain expended. This unusual mental strain is probably disconcerting and distracting with some children simply because it is unusual.

2. *Speed and Accuracy.* It has generally been assumed that speed and accuracy of work are antagonistic, that those conditions which favor speed are detrimental to accuracy and *vice-versa.* Our results fail to support this assumption *in toto.*

In the act of copying, speed and accuracy were antagonistic for ten of the eleven subjects when either was voluntarily emphasized. One subject was able to increase speed voluntarily without any sacrifice of accuracy. There was no antagonism, however, between speed and the tendency to notice and correct the errors made.

In making additions, speed and accuracy were not antagonistic when either was voluntarily emphasized. All subjects could increase speed without any sacrifice of accuracy, but the unsuccessful attempt to increase accuracy involved a diminution of speed.

The divergent results in copying and addition may perhaps be attributed to the more familiar and habitual character of the latter process. The former being less fully automatized is more susceptible to disturbance by shifts of attention.

Speed and accuracy are not antagonistic, however, in relation to an individual's normal habits of work. They are in fact, independent variables for both copying and adding. Speedy individuals may or may not be accurate, while relatively accurate subjects may be either slow or rapid workers.

It is evident that no simple relation obtains between speed and accuracy applicable to all conditions. Rather it is to be surmised that the relationship is quite complex, varying with numerous conditions.

3. *Initial and Final Spurt.* In copying, the phenomena of an initial and end spurt are manifested in both speed and accuracy. The initial spurt is generally more dominant. The records of the group average indicate that there is no uniform temporal fluctuation during the successive intermediate periods.

4. *Efficiency and Length of Task.* Efficiency in the speed of adding depends on the length of the daily task. The shorter the task, the greater the speed. There is, however, no evidence that within our limits of work the number of errors per unit is proportional to the length of the day's task.

The greater speed for a short task may be due to caution on the part of the subject. He tends to go slow or fast in accordance with the longer or shorter length of the work.

5. *Practice Effects.* The record of speed in making additions for the two groups indicates that the effect of practice was limited to the first few days of work. No further improvement was manifested continuously. The same tendency was also shown in the act of copying.

It is difficult to determine whether or not under these conditions practice is an aid to accuracy, owing to the high degree of variability in the error records, although there is some indication similar to the case of speed.

6. *Memory and Efficiency.* In our experiments memorizing processes reflect the following influences:

a. Age is one of the important factors in determining the relative effectiveness of reproduction. Our results clearly indicate that the average percentages of reproduction increase as the average ages advance up to maturity.

b. Sex is another factor affecting the relative efficiency of recall, especially with children. On the whole the girls secured better records than the boys. No sex difference was manifested in the adult group, since men and women obtained equal percentages of recall.

c. The order of exposure affects the efficiency of memory. The regular order of exposure is more effective in reproduction than the irregular order.

d. Meaning in memory, as is generally recognized, is decidedly significant. The high percentages of reproduction for meaning series and the lower percentages for nonsense series are definitely observed in both adults and children. In the meaning series, concrete words, which aid vivid impression and rapid association are more effective in the mental activity of recall than abstract words.

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The Interference of Will-Impulses

With Applications to Pedagogy, Ethics and Practical Efficiency

By

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NOTE.

This monograph constitutes the first part only of the investigation on the interference of will-impulses. The second part dealing with the complex processes of writing lapses is to appear separately.

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INSCRIBED TO

PROF. J. W. A. HICKSON

WHO FIRST TAUGHT ME THE ELEMENTS OF
SCIENTIFIC METHOD AT
McGILL UNIVERSITY

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MUTUAL INTERFERENCE OF WILL IMPULSES

PART I

CHAPTER I

INTRODUCTION

It is only within the last decade or so that the psychology of movement and the broader aspects that it involves has been coming to its own. Thus in 1899 we find Woodworth saying:

> "In all sorts of psychology, save one, there is of late an increasing interest in the motor side of consciousness . . . . In view of all this interest, it is somewhat surprising that . . , we have as yet no psychophysics of the voluntary movements,"[1]

while H. L. Hollingworth, two years later, opens his monograph,[2] which is on the complementary phase of Woodworth's problem, with the following paragraph:

> "The student of the psychology of movement is, to say the least, not hampered by the novelty of his subject. Ever since the days of the muscle sense controversy, investigator after investigator has interested himself in the subject of movement until a considerable body of motor psychology . . . has developed."

Since those words were written, the motor phase of psychology has kept steadily advancing, receiving its impetus from various quarters and forming the basis for new tendencies in that science. Our text books no longer discuss the subject of "action" as if it were a mere appendix to "will" or "habit"; and just as perception and its various adjuncts would formerly form the basis for many an all-embracing theory, so now "history repeats itself" in the domain of movement. Indeed, there is even a tendency to barter consciousness for movement among a certain type of psychologists.

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[1] B. S. Woodworth: Accuracy of Voluntary Movement, p. 1. *Psychological Review,* Monograph Sup., vol. III.

[2] H. L. Hollingworth: Inaccuracy of Movement. Archives of Psychology, vol. II.

And yet with all the due and, in some cases, undue emphasis on the motor side of psychology, there is no denying that it has always to catch up with the ground traversed in the sensory sphere; and this in spite of, or perhaps rather just because of the fact that ontogenetically movement is prior to consciousness. The underlying motive of this neglect seems to be the argument that since psychology is the science of consciousness, the consideration of movement has no place here—thus overlooking the fact that "the transition from reflex action to volitional is not abrupt and short."[3] With slight modification, the statement made by Woodworth in his dissertation nearly 20 years ago, that "we have nothing in this line that can compare with the immense amount of work done on the relation of perception to the stimulus perceived, or . . . that can compare in completeness with the work done and still doing in all departments of sensation"—this statement holds good even to-day.[4] Particularly is this true to-day of the psychophysiological phenomena included under the head of inhibition and springing from a volitional source.

So far, inhibition has primarily been a subject of discussion for the physiologist, while the so-called "inhibition of ideas" has made it appear as a relic of a by-gone age in the development of psychology.[5] Ever since Sherrington published his first results on the rôle of antagonistic muscles in movement, numerous investigators have followed along the same track, and it is to them that psychologists look up. The results of such investigations need not be underestimated, but they are within the scope of psychology only in an extended sense. It is important that the psychologists take cognizance of the facts disclosed by such investigations, but outside of this, they do not form the subject-matter of psychology. Psychology, as we shall see presently, has its own problems in inhibition; and with the exception of sensory inhibition, these problems have received little attention, if any, at the hands of the experimentalist. Sensory inhibition, too, has by no means received anything like adequate treatment in the laboratory.

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[3] Sherrington: Integrative Action of the Nervous System, p. 389.

[4] It is interesting to note that of all the psychological primers and text books known to the writer, only one syllabus, by Heath Bawden, reverses the conventional order of topics, and begins with the outline of action instead of reserving it to the end.

[5] *Cf.* B. B. Breese: On Inhibition (pp. 6-17, *Psychological Review,* Monograph Supplements, vol. III) for a historical summary of the views on psychological inhibition and a brief but concise discussion of its status as a term in contemporary psychology.

Partly the deficiency is due to the *dynamic* character inherent in all phenomena of inhibition. Theoretically we have rid ourselves of the implications of the old faculty psychology; *practically,* however, the average psychological investigator is still drawn along by the momentum of an old impulse. Broadly speaking, it may be said that the study of sensation, perceptions or feelings is, in the minds of most of us, connected with the study of facts (elements). To study inhibition is to study acts (relations). That is one reason why the cognizance of inhibition as a psychological phenomenon was so late in developing. Inhibition involves a community of sensations, memories, impulses, etc. The very circumstance that brought about the growing interest in association theories contributed to keep the facts of inhibition in obscurity. Association was recognized as a "force" as early as the period of Hume, because it gave evidence of governing the "faculty" of memory. It would have been difficult to conceive of such a negative thing as inhibition in connection with some faculty or ability. Association was the attraction of one idea to another. There seemed to be no room for inhibition, because there was apparently no use for it. It was left for physiology to lead the way in emphasizing the importance of the inhibitory mechanism, until gradually a new stratum began to form in psychology, and sooner or later inhibition is bound to be reckoned with in the ordinary text book as a fundamental relational category bearing on all the elements of consciousness.

There is a further drawback in the study of *impulse* inhibitions. The field of volition is not a clear-cut segment of psychology. With the exception of thought, there is more misgiving here than in any other part of general psychology. The crux of volition is shifted from one thing to another in the various text books and treatises. Thus it is that the problems subsumed under the possible head of volition are linked on the one hand with the most abstruse philosophical speculation, while on the other hand, they are transferred to the physiological laboratory[6] as if it were all a matter of muscle and nerve alone.

The play between these extremities is so great and is beset with so many difficulties that from one of the main results in this very investigation,* the neglect of this field of psychology might be expected. In turning to sensation, perception, imagination, and even affection, there is a feeling that the ground is at least a *terra cognita.* Volition does not present that aspect. And yet the concept of will is second to none in importance from the standpoint of a cultural philosophy. Those very psychologists who subordinate this concept to what they consider a more palpable, and therefore, scientific term, do not fail to make much ado about this time-honored notion of *will* as soon as they need it for other purposes, such as emphasizing its value as a principle in education.

Will, together with all the phenomena generally included under its head, is undoubtedly a factor in life that cannot be overestimated. That, however, is true from an intentional point of view. The negative counterpart of will, viz., inhibition, is the factual and explanatory portion of the story. Volition is possible only because inhibition is possible. The former posits the the latter. Not only is this true of the formal relation between these two concepts, but also psychologically.

In the most general terms, an impulse is an idea that obtained its promotion at the expense of its congeners, *i. e.,* it could only become an impulse after, and because all the other elements in consciousness have been inhibited.[7] If this inhibition lasts sufficiently long, the impulse realizes itself into action. We say then the agent has willed the act. Had other ideas inhibited the usurping idea, the impulse would not have been willed, hence not realized.

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[6] This brings to mind that as early as 1865 the temporal relation of voluntary acts was studied in the Tübingen Physiological Laboratory by W. Camerer, who published his dissertation "Zeitlicher Verlauf der Willenshandlungen" in 1866.

* *Vide infra,* p. 37.

[7] The "double reciprocal innervation" of antagonistic muscle may be regarded as the purely physiological manifestation of the same principle. *Cf.* Sherrington: Integrative Action of the Nervous System, p. 83 ff.

In spite of the great importance of this correlative of will, it is only natural that the positive concept should have remained the magic word to this very day. Our practical interests always take precedence over our scientific demands, since analysis as an activity is only a part of and not co-extensive with life. In life we are constantly on the lookout for results and scarcely ever for the indispensable conditions that bring about these results. Hence the Will that is so prominent in the history of philosophy, and especially in ethics, the very concept which forms the basis for all non-scientific literature including history, rhetoric and biography, will ever remain supreme in its proper sphere. For the man who is concerned with interpretation or exhortation cannot but take recourse to such a concept; and that is what we are doing all the time we are not engaged in describing or explaining phenomena.

It is perhaps owing to this universality of the popular concept "will" that psychologists generally have adopted the word "volition" to differentiate the psychological sense from the broader use of the term, and for the unit of volition let us take the will-impulse or simply the impulse in its generic sense.

If the correlative principle in volition were to be stated in the briefest form, it might be as follows: "no will impulse without inhibition" (of other possible or incipient impulses). Let us go a step farther now, and ask ourselves: what happens when there are two or more impulses, perhaps a whole series of them, going on almost simultaneously or in quick alternation? It will be evident that we have here a more complex and more interesting situation than in the first case; this leads us to the formulation of the problem of our investigation.

Note on Impulse.

It is of course evident that the word "impulse" is not used here in the popular sense as corresponding to the German word "Trieb." In many text books impulse is identified with striving. Thus Hôffding (Outlines of Psychology, p. 322) says "In impulse proper there lies always a more or less conscious demand." In our usage the term impulse may be defined as "any tendency to action." Unquestionably it would be desirable to have two distinct terms for the two different usages, but there is no reason to suppose, in the present stage of psychology, that what conditions the impulse psychologically is: "that with the momentary feeling and sensation, there should be combined a more or less clear idea of something which may augment the pleasure or diminish the pain of the moment." (Hôffding: loc. cit.) The psychological state that Hôffding is describing is of biological and ethical significance rather than psychological; and it must be apparent that if we have one word to designate two psychological states, the simpler and more elemental one should get the preference.

Referring to the impulsive act as it is commonly called, Wundt says: "Willenshandlungen von dieser Beschaffenhait pflegt man *Triebhandlungen* zu nennen, und die ältere Psychologie hat sie meist als spezifisch verschiedene Vorgänge dem Willen gegenübergestellt.

'Die einfache selbstbeobachtung lehrt jedoch, dass in allen den Fällen, wo es sich um einen wirklichen Bewusstseinsvorgang, nicht etwa um eine blosse Reflexbewegung handelt, zu einer solchen Scheidung nicht der allergeringste Grund verliegt."[9]

A determination of the terms we are handling is really necessary at the very outset in order to avoid possible misunderstading subsequently.

Personally the writer is in favor of applying the term impulse in four different senses to cover the demands, however, of four different sciences or disciplines. Thus we may talk of a physiological impulse, a psychological impulse, a biological impulse, and an ethical impulse. In the physiological sense it would be the mere nerve impulse. All reflex action would come under that head only. The psychological impulse should include all tendencies to action which are accompanied by consciousness and should form the unit of volition, whether that tendency be more like an impulsion and thus fought against by the individual, or whether it follows a process of careful deliberation. The impulsion may not be identified with the will of the individual, but it is a volition none the less. There remain the biological impulse, which is often used to designate a certain phase of instinct, as when used in connection with sex, Höffding's definition fitting in here quite well, and lastly the ethical impulse, which emphasizes not so much the act as the object or rather the whole situation in question.

There is no harm in employing a term to connote different things in accordance with the requirements of different departments of knowledge, provided that the different connotations are distinguished and agreed upon.

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[8] A similar view is found in Külpes' Outlines of Psychology, p. 322.

[9] Wundt: Grundzüge d. Phys. Psychologie, vol. III, 5th ed., p. 247.

CHAPTER II

THE PROBLEM STATED.[10]

Although the title of the investigation might easily convey an idea of the nature of our task, it might be of some advantage to state the problem in some such form as this: Given two kinds of impulses in rapid alternation in what way do they affect one another?

Such a situation is certainly not rare. It is not only in a case of emergency where one is apt to "lose his head" because he attempts to do several things at a time, but even in our daily routine we often find ourselves "crowded." More work is planned than can be done under normal conditions. At times we are like the British premier who would rise half an hour too late every morning and then rush about in the attempt to make up for the delay. Again we may be in the position of one who has a definite and peremptory task before him which is physically almost impossible to perform in the time set for it.

It will be seen at once that the principle here involved might have far-reaching ramifications, bearing in its practical applications on executive ability, pedagogy, and possibly the study of abulia and allied mental abnormities. In industrial efficiency the question looms even larger. Many failures, accidents, and indeed, catastrophes, are due to the fact that a task calling for quick action on the spur of the moment overtaxes the ability or skill of the responsible person. We have only to bring to mind the every-day experience of the sea captain or the motorman to realize how momentous it is to grapple with a problem that is at the basis of our very safety.

In the opinion of a director of one of the largest steamship companies, two types of ship officers are largely to blame for accidents at sea. "They all know exactly what is to be done in every situation" this keen observer told the late Prof. Münsterberg whom he was consulting about ship-service discrimination tests, "but there are too many who do not react in the appropriate way when an unexpected combination of factors suddenly confronts them, such as the quick approach of a ship in the fog . . There are ship officers who know the requirements excellently, but who are almost paralyzed when the dangerous conditions suddenly threaten. Their ability for action is inhibited. In one moment they want to act under the stimulus of one impression, but before the impulse is realized, some other, perhaps rather indifferent impression, forces itself on their minds and suggests the counteraction, and in this way they vacillate and remain inactive until it is too late to give the right order or to press the right button. The other type feels only the necessity for rapid action, and under the pressure of greatest haste, without clear thought, they jump to the first decision which rushes to their minds. Without carefully considering the conditions really given, they explode in an action which they would never have chosen in a state of quiet deliberation. They react on any accidental circumstance, just as at a fire men sometimes carry out and save the most useless parts of their belongings."[11]

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[10] The investigation was begun at the suggestion of Prof. Münsterberg, by Dr. V. V. Anderson, Boston Municipal Court Physician and Psychologist who, however, did not complete the experiments, and has not published any of his results.

Considering the similarity of the general situation, we should suppose that the same observations might apply *mutatis mutandis* to the motorman, the railway engineer, the army officer, and, in brief, all who are intrusted with some delicate task involving many factors of an unpredictable nature. The statesman, the public speaker, the business man, the attorney, are constantly encountering difficulties in the form of rapidly changing situations. A quick repartee may carry the day for one. An ineffective move may spell disaster.

Thus the practical side of the problem is important, indeed, but our primary interest is theoretical. We shall consider first: *What are the phenomena, both conscious and unconscious, resulting from a condition of rapidly alternating impulses?* The practical considerations that may be deduced from the results will be taken up towards the end.

It must further be understood that we are not concerned here with the problem of moral choice between two duties or tasks.

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[11] Münsterberg: Psychology and Industrial Efficiency, p. 84.

Undoubtedly the painful scruples and vacillation of Hamlet, the inner struggle of Antigone, the sufferings of Werther have some connection with the issue at hand. In comparing the details of the two sets of problems, we may find a certain overlapping with regard to the determining processes, but there is at least this great difference between them. In the one, the result hinges on *time* as the determining factor, the aim in the first instance being to complete the *whole task;* while in the other the condition *ex-hypothesi* involves a *moral choice* between two things, though both of them may be *desired* by the agent.

The conflict of impulses that we experience in every-day life when we have before us two courses of action brings us closer to the issue at hand. Some of these conflicts, because of the consequences that are at stake, may be grouped under the class just mentioned. Even in those cases where the decision is finally made on a purely prudential basis, psychologically the principle is the same as in the most striking ethical situation.

A great many of the decisions we have to make are, however, not related to moral matters, and those individuals who are not slaves to habit and have no decided preference will constantly find themselves confronted with the task of making a decision which, for the expenditure of energy it often calls for, is not at all commensurate with the importance of the consequences either way. "Shall I walk to the waterfall to-day? Or shall I ramble along the seashore?" is the illustration Herbert Spencer[12] gives us of a morally indifferent end. For the moral agent it may be entirely indifferent. Not so however, for the psychological reagent in whose mind a veritable conflict may occur.

Probably this is the type of behavior referred to in the following description of a conflict. "Adults sometimes experience such a state when two opposing courses are open to them and they have no decided reason for following either; they feel impelled first to one, then to the other, and in pathological cases the forces may be so evenly balanced that action is prevented altogether. As a rule, however, the permanent motive ideas are so numerous and so far-reaching that every suggested course of action is either helped or hindered by them."[13]

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[12] Data of Ethics, p. 6-7.

[13] Mellone and Drummond: Elements of Psychology, p. 173.

There is much in common between such a conflict and the issue at hand, but there is at least this difference in their respective conditions. In the common every-day situation, the agent knows that only one of the impulses can and need be carried out, while in the experiments to be described, the subject makes the *endeavor to carry out both sets* of impulses, and if a choice *is* made from the sheer physical impossibility of accomplishing the whole task, it is done in spite of his intentions. It is just this difference that distinguishes our investigation from those on choice such as Ach's and Michotte's researches (to mention only a couple of the more recent studies among the large number of investigations initiated by Donders).

Special emphasis must be laid on such a distinction in view of the circumstances that the field we are dealing with has been treated as a common trespassing-ground by speculative psychology, ethics and allied disciplines. Whether we should be disposed to go the length of Stout who claims that voluntary action in the sense of deliberate action (selective action probably according to Titchener) involves conception of the Self is quite a different matter, but at any rate, it is not difficult to concede that the status of deliberate action and non-deliberate action may possibly be determined by different variables. And when Stout draws the sharp dividing-line between "voluntary action" and "impulsive action" and also between "deliberation" and "conflict of impulsive tendencies" by saying "When two disconnected impulses simultaneously prompt to incompatible courses of action, if the conception of Self does not come into play, one interferes with the other in a quasi-mechanical way"[14] it must immediately become evident that the above-described type of action is what we are studying. It is the very "brute strength between them' as Stout puts it, that we are trying to compare; and from an experimental point of view it is something to be thankful for that it is capable of working out not only in a *quasi*-mechanical but in a thoroughly mechanical way.

Another preliminary point must be cleared up here. In the introduction of this study the impression may have been gathered that the writer had set out in the first place to investigate the nature of inhibition of voluntary impulses. Strictly speaking, this would have been an assumption, for the term inhibition has a more or less fixed usage in psychophysiology. As a matter of fact nothing was taken for granted. There was no theory to be given experimental confirmation, no foregone hypothesis to be tested out. The work was undertaken with no theoretical bias, a circumstance which has its disadvantage as well, though, in the long run, it is not as great as its advantage.

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[14] Stout: Manual of Psychology, 3rd ed., p. 706.

From education and observation we of course know that "no one can serve two masters well." Julius Caesar, it is said, was able to dictate several letters at one and the same time, but, granted that this fact about him was really not exaggerated, the persons who would have a claim to be classed with Caesar are, to say the least, very few.

Probably, if we were asked off-hand whether we thought two or more different acts or impulses would interfere with one another if aroused almost at the same time, we should be inclined to reply in the affirmative. It is very rare to find this sort of interference referred to in text books of psychology. LADD and WOODWORTH do mention it, but that is about as far as they get in saying:

"When a series of dissimilar acts must be performed in quick succession, one of these is likely to interfere with another."[15]

We may even be certain that the acts interfere with one another, but this does not mean that they necessarily inhibit one another; for interference is a broader concept than inhibtion. Interference is used extensively in physics in connection with the study of light, sound and electricity.[16] It also figures in philology[17] and in (pure) physiology, [18] as well as in sociology[91] and psychology.

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[15] Ladd and Woodworth: Physiological Psychology, p. 540.

[16] The phenomena of interference in physics are demonstrated in every elementary course and discussd in every text book.

[17] Hanns Oertel: Lectures on the Study of Language, p. 205: "The real causes which bring about those phonetic changes....are change of speed, which interferes with the proper co-ordination of movement."

[18] Especially in Sherrington's work.

[19] C. Tarde in his "Les Lois de l'Imitation" (p. 32), talks of *"interférences-*

Two beams of light interfere without producing necessarily a negative result. Under certain conditions colored bands appear. In the interference of sound this feature of the case is even more striking. Two sets of waves may interfere and yield a tone of increased intensity instead of producing silence which would be the analogue to inhibition in the psychophysiological sphere.

In the development of language "Increase of speed leads by no means always to simplification or loss of sound. The opposite also occurs."[20]

As regards the interference between a sensory stimulus and a motor impulse, LEHMANN tells us that "Sind die beiden Erscheinungen gleichzeitig, hemmen sie sich; geht aber die eine der anderen voraus, *bahnt* die erstere die letztere an,"[21] citing the following instance: if a subject manipulating an ergograph in a regular tempo should unexpectedly hear a pistol shot shortly before the muscular contraction had begun for the lifting movement, the next two or three lifting movements would as a rule be considerably greater.[22]

SHERRINGTON is inclined to talk of interference as close akin to inhibition, but even his language, as may be evidenced from such statements as "There is interference betweeen the two reflex-

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combinaisons" and *"interférences-luttes,"* thus showing that he makes a distinction between conflicting and non-conflicting interferences.

[20] Hanns Oertel: Lectures on the Study of Language, *loc. cit."*

[21] A. Lehmann: Grundzüge der Psychophysiologie, p. 436. *Cf.* also Wundt Grundzüge der physiologischen Psychologie, vol. I. p. 86 (5th edition) on interference of stimulations and I. p. 243. Interference in psychology is most frequently spoken of in connection with association, but more recently it has been studied in connection with memory images of MEAKIN (Mutual Inhibition of Memory Images, Harvard Psychol. Studies I), in connection with habit by MCMEIN and WASHBURN (Effect of Mental Type on the Interference of Motor Habits, *American Journal of Psychology*, 1909, 20) and by WARNER BROWN (Habit Interference in Card Sorting, University of California Public. in Psych. 1914, I), by Miss KLEINKNECHT in relation to Optical Stimuli (Interference of Optical Stimuli, Harvard Psych. Studies, vol. II) and by KELLOG, in connection with the feelings (Alternation of Feelings, Harvard Psych. Studies IV).

[22] *Cf.* especially L. Hofbrauer: Interferenz zwischen Verschiedenen Impulsen im Centralnervensystem. Archiv für die Gesamte Phys. (Pflüger) vol. 68, 1897, pp. 585 and 586.

es, and the one is inhibited by the other"[23] and ". . . There is an interference which is tantamount to, if not the same thing, as inhibition,"[24] implies that interference is the broader term, and is at least a stage prior to inhibition.

In the opinion of the writer, interference has reference to the *condition,* while inhibition is applicable to the result. It is thus legitimate for us to assume at the outset that the phenomena that we are looking for in our investigation would be those of interference, but having satisfied ourselves as to that purpose, there remains nothing but to grope about for preliminary data.

THE APPROACH.

In a problem such as the one before us, two possible modes of approach are possible. The one is quantitative, the other qualitative. In the former we are concerned mainly with the accumulation of data. There is no wide scope here for close analysis of the phenomena. The variations of the experiments all center around the idea of exhausting one line of procedure, the experimental situation being reduced to the lowest terms. The chief advantage of the quantitative approach is the decisiveness of the results whether positive or negative. In going over traversed territory, in testing out a theory or in dealing with a problem that requires for its solution the answer "yes" or "no", the quantitative method is the more serviceable one and is actually used just for those purposes enumerated.

The qualitative method which demands a more complex experimental situation does not yield so clean-cut and decisive results as the quantitative method, and more often calls for the aid of interpretation. It has this advantage, however: it affords an excellent opportunity for orientation in a problem, and the results it leads up to may point to new vistas that might have been left undetected in the other procedure.

In our study of interference both methods were employed. Simple movements constituted the task of the subjects for a time. The data spoke in hundreds of thousands. After a year of experimentation along this line, it became clear, however, that the vast array of figures wanted supplementing, and that the second mode of approach might shed some important light on the quantitative results.

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[23] Sherrington: Integrative Action of the Nervous System, p. 135.

[24] *loc. cit.,* p. 138.

That was just what turned out to be the case. It will be seen later in what way these two methods acted as complementary to each other, but for the present, it is only necessary to point out that, owing to this circumstance, this study has been divided into two independent parts. This does not mean, however, that we are dealing with two different parts of a problem. Distinct as the two methods are, they only brought out two different phases of the same problem. It would be quite permissible to treat the results yielded by both methods under the same rubric; but since the stimuli used and records obtained were dissimilar, it was thought best to treat all the subjects separately in the two parts, and thus avoid confusion. The data in the first part of the study will be referred to as the simple movement experiments; those in the second part will be called the graphic experiments.

CHAPTER III

Survey of Literature

The monographs and articles that might be said to form tangential contacts with the problem in question are numerous, but very few go beyond that point, and to the knowledge of the writer, there is not a single one among them that touches the central issue directly. No wonder TITCHENER says, referring to what is known about the conflict of impulses, "Here, however, psychology is sorely in need of further analyses."[25]

In the following paragraphs only the investigations that have some bearing on the first part of our study will be mentioned. Those dealing with the more complex movements will be reviewed in connection with the qualitative phase of our work.

Probably the first investigator who was on the way to study the influence of one motor impulse upon another was M. L. PATRIZI,[26] who set himself the task of ascertaining whether the "brain is more easily fatigued in sending out to the two halves of the body a series of double simultaneous impulses than in issuing an equal sum of unilateral impulses towards the right and left (periphery)."

With PATRIZI, the problem is more of a physiological character, following up the work of Mosso. He had his subjects use two ergographs, one for the middle finger of the right hand, and one for that of the left hand. At the two-second beat of the metronome they were to flex the two middle fingers. The main result here was that the succession of two voluntary impulses carried out by symmetrical members is more favorable for the central nervous system than for these impulses to be carried out simultaneously.

His conclusion is: "Il résulte de la présente étude que, le fait d'accomplir des efforts volontaires simultanés avec les deux moitiés du corps indique déjà la co-existence et par conséquent la lutte des deux actes psychiques distinctes: l'attention ne peut se porter en même temps sur les deux, mais il faut qu'elle néglige un, alternativement pour produir l'effêt maximum."

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[25] Titchener: Text-book of Psychology, p. 460.

[26] La Simultanéité et la Succession des Impulsions volontaires symétriques. Arch Italiennes de Biologie vol. XIX, 1893, p. 137.

Evidently then one might infer from the foregoing that simultaneity of symmetrical impulses is but a very rapid succession of impulses with an ensuing inhibitory interference. This result might have served as a starting point for a study of the mutual influence of rapidly alternating impulses, but PATRIZI's subsequent researches diverged more and more in the direction of fatigue investigations.

JASTROW[27] in a preliminary survey on the interference of mental processes set himself the task of finding out which processes hinder and which aid one another. He used two types of processes, (a) the performance of finger movements, involving rhythm and counting, (b) processes such as adding and reading under various conditions.

The question as to how far various movements will be interfered with by the accompanying processes is answered by the conclusion that the simpler movements are less interfered with than the more complex ones. In describing the nature of interference, he says that it manifests itself in an increased effort, a great irregularity, presence of errors and a lengthening of the time of movement, from which he infers that "motor processes . . . interfere with motor ones while refraining from movement during intellectual effort would be helpful."

HANS BERGER[28] studied the rapidity with which simple finger movements could be made uninterruptedly. He found there were fluctuations in the speed that suggested periodicity in the discharge of the required impulses. The same phenomenon was observable in his preliminary experiments on the rapidity of the volitionally excited eye-lid reflex. Here the subjects had no stimuli upon which to react, the instructions being merely to make the movement as fast as possible for a certain period of time without stopping.

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[27] JASTROW: American Journal of Psychology, vol. IV, 1891-2 p. 219 ff.

[28] BERGER: Über Periodische Schwankungen in der Schnelligkeit der Aufeinanderfolge Willkürlicher Bewegungen. Zeitschrift f. Psych., 1909. vol. L 321.

BERGER's results do not throw any light on the actual influence of one impulse upon another, for one reason that the required movements in his case were homogeneous, but his general conclusion regarding the phenomena of periodicity is important and will be brought up again later in discussing our results.

DRESSLAR's[29] study of voluntary movements might be mentioned here only in so far as one of his results seems to suggest that increased central activity produces increased rapidity in voluntary movements.[30]

Many of the experiments on practice, voluntary control, and fatigue, cover some of the facts of our present problem, but from a different angle. With regard to fatigue, it is interesting to note that several of the phenomena ascribed by YOAKUM[31] to fatigue conditions, have been obtained in our investigation where every effort was made to eliminate fatigue conditions as much as possible. These results will be discussed fully under another rubric where further reference will be made to such investigations as have some points in common with our work, even if the starting-point is different.

Probably the nearest approach to our problem of interference was a series of experiments carried on in BECHTEREV's laboratory in Petrograd. As reported by BECHTEREV,[32] the purpose of these experiments was to determine the "mutual influence of personal[33] movements." The series was begun by OSSIPOFF[34] who had his subjects go through flexion movements on the ergograph with the middle finger of the right hand, while at the same time they were to carry out, upon a given signal, other movements, either with the upper part of the body or else with the two lower extremities. The results are not striking. We learn, in the first place, that active movements of the other extremities or fingers or toes always modify the investigated movement, and that the degree of the influence depends upon the degree of muscular strain that is rquired for carrying out the investigated movement.

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[29] DRESSLAR: Some Influences which Affect the Rapidity of Voluntary Movements. Am. J. of Psych. vol. IV, 1891-2, p. 514-527.

[30] *Ibid.*, p. 523.

[31] YOAKUM: An Experimental Study of Fatigue, Psych. Review, Monograph Supplements 46.

[32] BECHTEREV: Objektive Psychologie, p. 444.

[33] The word "personal" is really equivalent here to the word "volitional." Since Bechterev designates his system of psychology, Psycho-reflexology, he has adopted the term "personal reflex" which seems to be a makeshift for purposive or volitional activities.

[34] Ossipoff: On the Question of the Coördination of Movements. (In Russian.)

This investigation, however, is after all, as the title suggests, one of coördination, and judging from the brief description of BECHTEREV, it does not go behind the results so as to throw any light on the relation of the impulses involved in the interference.

SOLOVTSOFF and BARANKEYEFF[35] who took up the supplementary phase of the foregoing problem, studied the flexions and extensions of two fingers, obtaining among others the following results: The investigated movement is affected by every other movement: the more complicated this primary movement, the greater the influence. The curve of the primary movement is more markedly affected by non-rhythmical movements than by rhythmical ones. The influence becomes less marked with repetition as a result of practice. Simultaneous movements of both extremities are often of less influence than the movement of the opposite extremity. Finally it is pointed out that the mutual influence of movements presents marked individual differences.

In these two investigations the movements were carried out simultaneously, or at least, that was the task of the subjects. But in the case of simultaneous movements, we really have one impulse; hence whatever interference occurs here is not an interference of impulses, for the impulse is to make both movements at the same time. As in the case of PATRIZI, the condition of *simultaneity* can, from one point of view, be regarded only as a preliminary step. To study the influence of impulses upon another, we must start out with the *succession* of movements as a requirement.

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[35] Solovtsoff and Barankeyeff: On Mutual Influence of Muscular Movements. (In Russian.)

Russian names have been transliterated phonetically. The Polish names, however, retain their original spelling for the obvious reason that the Polish alphabet is, except for the accents, the same as our own.

In LANGFELD'S[36] work on simultaneous and alternating finger movements, additional light is thrown on the succession of motor impulses. LANGFELD examined the relation between the different finger movements of both the right and left hands with regard to facilitation and inhibition. The object of this investigation was different from the one which we are concerned with at present; which means naturally that the methods in each case were not the same. One main difference was that LANGFELD'S problem did not call for any presentation of stimuli. The subjects were simply instructed to react one way or another, and though the movements must be regarded as of volitional origin, the process might have gone on automatically, once a start was made. Only in the complete alternation series where the subject was not to begin moving the other finger until the first was brought to rest on the tapping board can we talk of a species of stimulation occurring, viz., auto-stimulation. Whatever interference it was that gave rise to the considerable degree of inhibition as shown in that series of experiments, especially with complete alternation, we cannot ascribe it to the same processes that would be involved in a situation where the subject is to react to a series of *presented* stimuli, simply because the conditions are missing that would give rise to those presumable processes.

The significant result in LANGFELD'S work is, for our purpose, the increasing inhibition with the increased voluntariness (complete alternation) of the tapping, and also the fact that there is no appreciable gain through practice in these movements as compared with the simultaneous tapping movements.

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[36] LANGFELD: Facilitation and Inhibition of Motor Impulses. Psychol. Review, vol. XXII, 1915.

CHAPTER IV

A. Report of Experimentation

The experiments to be reported were carried on in the Harvard Laboratory during the academic years 1913-14, 1914-15. Nine subjects took part in 1913 (3 dropping out after the first term), 10 in 1914, and 12 in 1914-15. In all there were 23 subjects. These were: Prof. H. S. Langfeld (Harvard), Prof. J. W. Bridges (Ohio State), Dr. H. Burtt (Simmons), Dr. R. C. Givler (Washington), Dr. E. C. Kellogg (late at Minnesota), Prof, H. T. Moore (Minnesota), Dr. S. L. Pressey (Indiana), Dr. E. C. Tolman (Northwestern), Dr. L. T. Troland (Harvard); Miss F. Brotherton, Miss O. Martin, and Miss M. Seeley (Mrs. Givler); Messrs. Avery, Beazley, Beery, Sturges, Cutting, Davidson, Finkel, Fry, Marston, Nutter, and Sugarman. Of these the latter 7 were not college graduates at the time, but had had considerable training in psychology. Prof. Langfeld and Drs. Burtt and Troland participated as subjects during the entire work, i.e., both in the simple movement and graphic experiments. Occasionally, too, the writer himself acted as subject in order to gain more insight into the introspective accounts of the actual subjects. The records obtained in these occasional experiments, however, were not considered in the general computation.

The description of the method of procedure and apparatus in the following pages deals only with the simple movement experiments carried out during the academic year 1913-14.

B. Method of Procedure

The *apparatus* consisted of a brass cylinder, a kymograph, a screen, and two telegraph keys. The cylinder, which was run by weights, was used for exposing the stimuli, while the kymograph with smoked surface served to record the reactions of the subject.

A long series of green dots and red crosses formed the *material* for the stimuli. These symbols drawn in ink represented two different movements to be made by the subject. Each series was made up of about 85 dots and crosses, and represented one revolution on the cylinder. The period of work covered six continuous revolutions, and as the single revolution took 33 seconds (28 for the very quick reagents), it means that the subjects worked for a continuous period of 3 mins. 18 secs. There were two such periods at every sitting. In every case the subjects were allowed a sufficient rest interval between the two periods.

The rate of the revolution was constant, but the stimuli on the list were arranged at increasingly shorter intervals.[37] Thus the subjects would have to keep constantly increasing their speed in order to perform their task. The intervals between the dots and crosses ranged from ¼ of an inch to 4 mm., which gives a range of from 2 stimuli per second to 3.18 per second. In this way the subject was started with something he could do with a little effort, but which he could not continue doing for any length of time. It is obvious that to use the same rate for every subject would not satisfy the requirement of the experiment. Hence the very quick reagents who found no difficulty in performing the task in 33 seconds per revolution were given a more rapid rate (28 secs.). Each reaction to a stimulus consisted of two taps on the telegraph key, the details varying with the different variations of the experiment. A single sitting thus called for over 2,000 taps or single reactions. The keys were placed a few cm. apart so as to prevent making the two different movements in response to one stimulus.

General Arrangement. The subject sat in front of a large screen with an opening (2 × ½ cm.) large enough to expose 3 or 4 of the stimuli. A small square of mirror pasted on the back of the screen just above the opening served to illuminate the stimuli just as they would come into view. Beginning with the first variation, an arm support was used for the purpose of eliminating as much as possible fatigue and discomfort.

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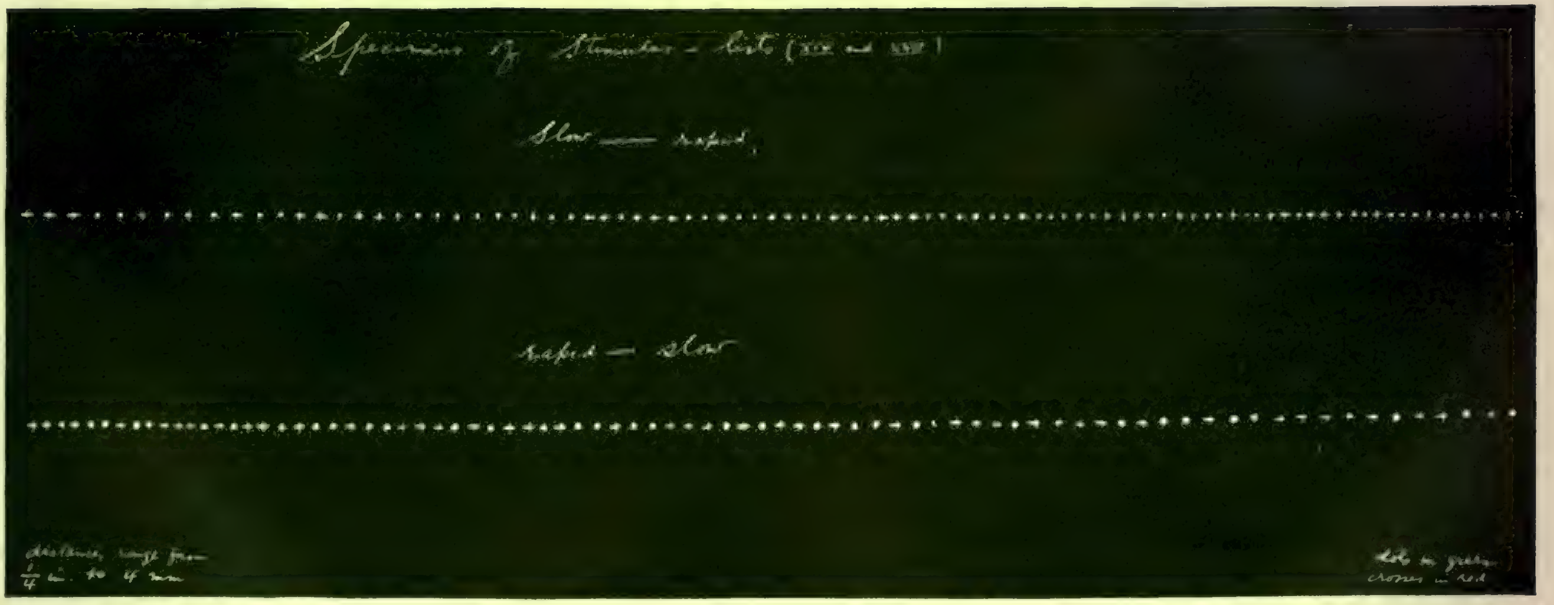
[37] There were a number of preliminary experiments with a somewhat different method where the stimuli appeared at equal intervals, but the rate of the revolution was changed each time.


Specimen of Stimulus-lists ([illegible] and [illegible])
Slow —— rapid.
rapid — slow
distances range from
1/4 in. to 4 mm
dots in green
crosses in red

After every one of the six revolutions of the stimuli-series there was a break where the two extremities of the paper list would meet on the metal cylinder. The break was never more than 5 mm. in length, and served as a signal for the subject to say "now." The spot was then marked by the experimenter on the smoked paper as separating one revolution from another.

At the suggestion of Dr. Troland, the following device was made for the purpose of obtaining a model or objective record with which the subjects' records could be compared. Two metal brushes were attached to a wooden square which was glued on to the back of the screen a few cm. above the opening. These brushes extended far enough so as to touch with their looped ends the stimuli-list as it was revolving on the brass cylinder. On the stimuli-list, slits were cut out above the red crosses and below the green dots. These slits formed the locus for the brushes, making an electrical contact every time the brush touched the cylinder, it being understood, of course, that the brushes were connected with two additional markers registering the "model reactions" on the smoked paper.

It was found afterwards, however, that it took less time to compare the subjects' records with the original stimuli-list than with the model record, and also that the latter method was not so safe as the former, due perhaps to technical flaws in the construction.

C. Instructions

The instructions to the subjects were both general and particular, the former having reference to the experiments as a whole; the latter, to the separate variations.

The general instructions to the subjects were to consider the task as if it had to be done *in toto,* but should they find it impossible to meet the requirements, they were to use their own judgment. They were not told to lay more emphasis on accuracy or speed or some one specific factor. Such an instruction might easily mar the results; for those very individual differences that the various types of reaction would reveal in our work are of paramount importance.[38] Secondly, cast-iron rules would, in this case, be not only unnecessary, but a decided drawback, as the particular instruction might be a help to one subject, while to another it might act as a disturbing factor.

In the first set of experiments the particular instructions were to react to the red crosses by making a double up-down movement; to the green dots, by making a double centripetal* side-movement on the telegraph key, the latter being suitably arranged in a vertical position 3 cm. above and 5 cm. to the right of the key intended for the up-down movement. The forefinger of the left hand was to be used exclusively for the tapping of the key, but the side reactions necessitated the turning of the hand and the use of the forearm muscles.

D. Variations

The combination of stimuli varied from week to week. There were also several variations in the conditions of the experiment. In the first variation, the reactions were double up-down movements with the forefinger and the middle finger. The second variation called for the use of the middle finger and the ring finger; while lastly the index finger was again to carry out both movements. In the one, the key was hit with the tip; in the other reaction, the nail part of the finger was used. The reactions here were virtually flexor and extensor movements (downward and upward).

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[38] "When a person is given vague and indefinite instructions, he very soon helps himself out by adopting a stereotyped method and sticking to it, i.e., he adds self-imposed tasks to the one he has been set" (Washburn: Movement and Mental Imagery, p. 172-173).

It is not advisable to give such vague and indefinite instructions that would allow the subject to interpret his task with too great a latitude, but in experiments where individual differences are sought, it would be just as wrong to suggest in the instructions some one definite type of reaction as to do the exact opposite.

Cf. also Stern's injunctions: "Fragt er [the subject] etwa ob er seht schnell oder langsam, stark oder schwach klopfen solle, so muss die immer zu wiederholende Antwort lauten 'ganz wie Ihnen gefällt.'" W. Stern: Ueber Psych. der Individuellen Differenzen, p. 117.

* i.e., adductive or towards the median line.

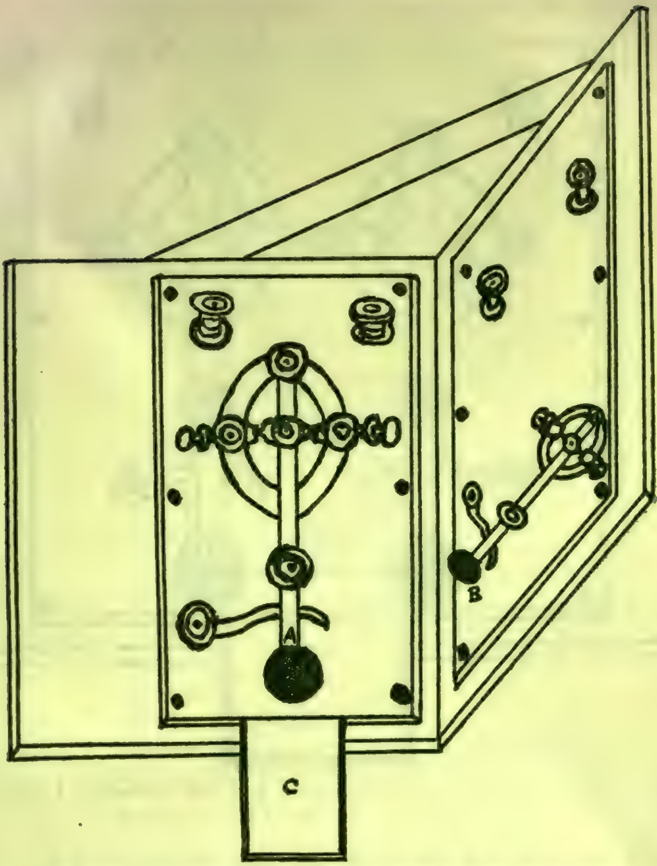

FIG. 1.—*Diagram showing position of keys for series* 1.

A. Horizontal key requiring downward movement.

B. Key in upright position for lateral movement towards the median line (adductive).

C. Arm-rest.

In all variations, care was taken to avoid disturbances due to confusion arising from reversed instructions. Only one change was introduced at a time, so that the association of stimulus and reaction became more or less stereotyped.

Of the twelve revolutions of the stimuli-list given at a sitting, six began with the closely arranged dots and crosses and ended with those farther apart, while the other six revolutions were

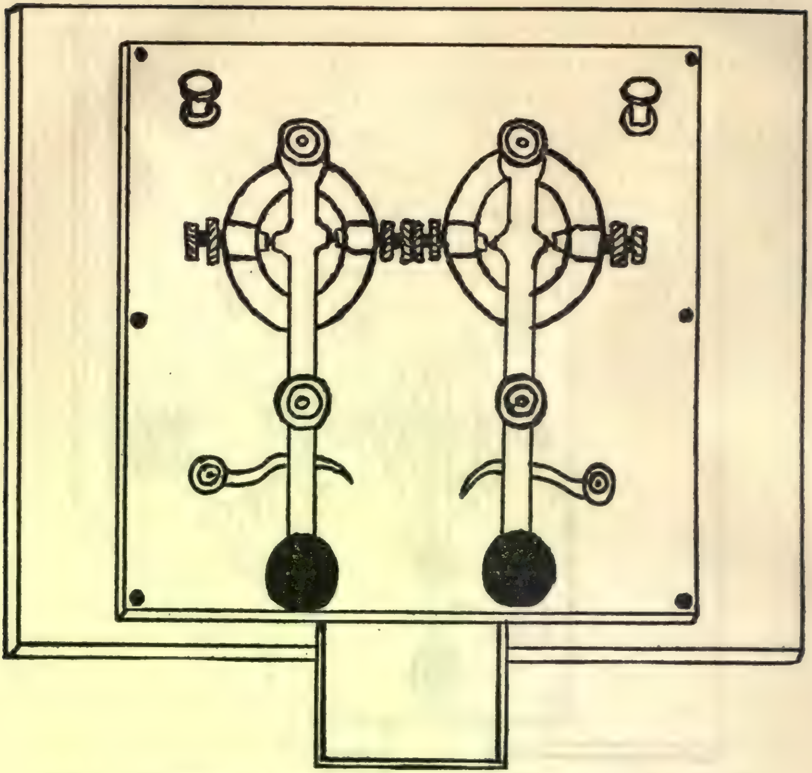

FIG. 2.—*Position of keys for Series II and III (variation* 1 *and* 2).

of the same list, but reversed, i.e., they began with the stimuli farther apart. This order of the lists was varied in alternate weeks. As far as the subjects were concerned, it was not one list, but two entirely different lists which they designated respectively "fast first" and "slow first" referring to the speed corresponding to the different parts of the series.

E. 'Spontaneous' Record

Towards the close of the simple movement experiments, the subjects were given a slightly different task. They were asked to go through the same kinds of movements as before, but without any stimuli before them. They were simply to react on the basis of their impression of previous arrangements, or rather of

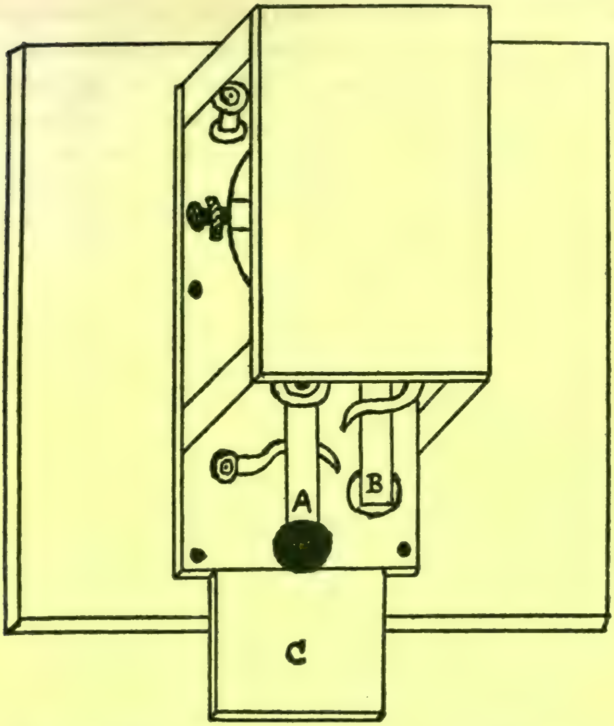

FIG. 3.—*Position of keys for series IV (variation 3).*

A. Horizontal key struck with palm or side (tip) of forefinger (flexor movement).

B. Key facing A struck with dorsal side (nail part) of forefinger (extensor movement).

C. Arm-rest.

the 'feel' of the general rhythm in former experiments. This might be called a 'spontaneous reaction' test, the purpose of which was to compare the subjects' spontaneous reactions with those in response to a strained and constantly changing situation. In all other respects the situation was the same, the record on the drum being divided into six equal parts of 30 secs. each so as to represent the six revolutions of the stimuli-list. The movements were as in the third variation (forefinger flexor and extensor movements).

F. Tests as to Difficulty

Before evaluating the results it was necessary to ascertain the relative difficulty of the different reactions. We may easily suppose that an up-down movement, such as is done in ordinary tapping, is much easier to perform than a centripetal side-movement. All the subjects spoke of the latter as being by far the more difficult of the two. To rely, however, on the statement of subjective difficulty by the subjects would be an assumption which might not be borne out objectively. For this reason, short tests (1 min. and 30 secs.) were given with every variation, where the subjects were required to go through one reaction continuously as rapidly as possible until the signal was given to stop. The same was done with the second reaction. By counting up the actual number of single continuous reactions of the two different movements, the writer was able to compare with definiteness their motor difficulty.

G. Auxiliary Experiments

In order to get at the conscious content during critical moments and also to clear up some of the data appearing again and again in the protocol, a number of experiments were given for the sake of introspection alone. There are very few problems in which a minute analysis of the introspective content counts for so much as in the phenomena dealing with the higher thought processes and the neighboring problems. It is just here, however, paradoxical as it may seem, that "thought" seems to elude us most. Especially is this true in our present work. The subject who is straining every muscle to accomplish the physically impossible, so far as he is concerned, cannot be expected to hold in mind the intricate details of his experiences during the 3.3 mins. that he is at work. Repetition, as has often been suggested, will bring out, doubtless, more and more of the elusive material. ACH,[39] it will be remembered, relied wholly on perseverative tendencies for introspection. This confidence in the recurrence of the memory image is, however, not shared by G. E. MÜLLER.[40] It is agreed on all hands that introspection is at bottom retrospection, but it makes quite a difference as to what degree of retrospection it is; in other words, the value of the introspective account will depend largely on the period of time elapsing between the actual experience and the reproduction by the subject. Hence, the sooner we can exploit the subject's material the more certain we are of our find.

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[39] N. ACH: Willenstätigkeit und das Denken p. 19 ff. In his later work "Ueber den Willensakt und das Temperament" the general methodological view is the same.

[40] G. E. MÜLLER: Zt. f. Psych. Ergänzungsband V, 1911, p. 122: Zur

It was in accordance with this principle that the additional experiments had been introduced. The purpose was to catch the conscious experiences in the process of congelation. Instead of waiting till the working period was finished, the introspection was given at the crucial moment.

This auxiliary method was carried out in two ways: In the first place, the subjects were asked to stop their work as soon as they noticed anything striking (mistakes, confusion, definite inhibition, etc.) and to describe their experience at that point as closely as possible. Or they were told that at a certain stage in their work, the cylinder presenting the stimuli would stop revolving. At that point they were to reproduce on the instant their whole content of consciousness with its antecedents. In the latter case, i.e., whenever the break was conditioned by the experimenter, the machine was usually stopped while the subject was reacting to the closely arranged dots (highest speed). These auxiliary or control experiments were given towards the end of the hour, after the subjects had already made two kymographic records, and had therefore ample opportunity for introspection in the earlier part of the hour.

H. The Questioning

The questioning of the subjects is another source of perplexity. How much is to be asked, and how exacting ought the experimenter to be in taking introspection? Should the sub-

Analyse der Gedächtnistätigkeit und des Vorstellungsverlaufes, pp. 139-143. **Müller** is quite emphatic in his disapproval of **Ach**'s method. "Ich würde eine Versuchsperson wegen offenbarer Flunkerei mit Schimpf und Schande von dannen jagen, wenn sie mir erklären würde, dass sie alle oder wenigstens viele der dort angeführten Fragen beantworten könne, indem sie ihre Aufmerksamkeit bald dem einen bald dem anderen Teile des perseverierenden Inhaltes zuwende" loc. cit. p. 140-141.

ject be closely and "systematically" questioned, as ACH was inclined to believe all through his work, or should the call for introspection be general and under no circumstances insistent?

The writer followed a midway course. Probably most psychologists would approve of G. E. MÜLLER's caution not to overwhelm the subject with a volley of questions;[41] and the criticism levelled at ACH to the effect that the subject is liable to believe that the score or so of questions must be definitely answered—is not without point. Yet, on the other hand, it must be pointed out that unless there is some guiding control, the introspection is so scant and often so irrelevant that it is scarcely worth while recording. In our particular case, for instance, though most of the subjects were trained observers, they were inclined to content themselves in the early stage of the experiment with stating such perfectly obvious facts as "Had to omit because it was too fast," "The one movement conflicted with the other," etc. Now it is clear that such statements cannot contribute to our knowledge regarding the mental processes responsible for these very omissions and other resulting phenomena. The subject must be given some idea as to the dimensions of his task. He must at least be given to understand that his *Aufgabe* includes introspection as well as going through the actual work of the experiment. So many are prone to believe that their task merely consists in performing the required reaction, and that introspection is at most a by-product—something that goes into the bargain. While this attitude is the very thing advocated, and in its extremest form at that, in certain radical quarters, and is to a certain extent allowable in quite a number of experiments, it certainly cannot take us very far in such a problem as the one before us.

What the writer did in the way of guiding the subject was to ask him to illuminate his introspection by further analysis. When, for example, the term 'conflict' or 'inhibition' occurred in the protocol, the subject was requested to describe the experience more fully. As a rule, the effect of this exhortation was noticeable only in subsequent sittings, but not at the time the questions were first put. The significance of the introspective task seemed to grow on most of the subjects. Those, however, who proceeded no farther than to say what could easily be told by consulting their kymographic records, were never urged to give more details, except in explaining the terms employed by them. Fortunately it may be said that ACH's finding "Vor allem scheinen gut geschulte Psychologen nicht besonders brauchbar, da sie zu vorsichtig sind und infolgedessen andersartige Determinationen nicht wirksam sein können"[42] was not confirmed here. It was decidedly the more advanced subjects who showed better orientation in their introspective situation.

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[41] G. E. Müller, loc. cit. p. 122.

I. Arrangement of Results

Before concluding this chapter, a few words may be in order relative to the general arrangement of the results in this study. The results are treated under three separate heads: (a) those based on the kymographic records, (b) those based on the protocols, (c) individual differences. The correlation will be evident from occasional cross-references and also from the synthesis of the results.

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[42] Ber. über den II Kongress f. Experim. Psychol. 1907. p. 256 cited also in his reply to Selz "Willenshandlung und Temperament," Ztschft. f. Psych. vol. 58, 1911.

CHAPTER V.

OBJECTIVE RESULTS.

The objective results of the simple movements are based on over 500 kymographic records or about half a million single bits of data. In computing the results there were, of course, one or two drawbacks that no conceivable technique could remedy, but the introspective account filled out some of the gaps.

The task of the writer was naturally to compare the original stimuli-list with the actual work done by the subject as revealed by the records.

A. Method of Computation.

Since it was possible for the subject to go wrong in four different ways, *viz.,* (a) to give single reactions instead of double ones (see instructions), (b) to omit the entire reaction, i.e., the double tap, (c) to *add* single reactions, (d) to add double reactions—the figures were arranged in 8 columns, i.e., 4 columns for each of the two movements.

The double reaction representing a single stimulus is the unit. Single reactions were marked ½. The plus sign denotes that the movement has been added, with no stimulus to correspond to it; the minus sign is used for omissions. Each revolution of the stimuli-list was computed separately, so that the course of the work could be followed from revolution to revolution.

As the tallying proceeded, other phenomena besides omissions and additions were noticeable on the records. It was possible to tell long inhibitions, rhythmic activity, and various other things that will be described presently. Unfortunately it was very difficult indeed to spot mistakes, i.e., wrong reactions. Tracts of utter confusion could be detected much more easily.

B. General Results.

The inhibitory effect of one impulse upon another is the most marked, though by no means the most instructive, phenomenon in connection with the entire mass of data. We can now amend the statement cited from LADD and WOODWORTH's Physiological Psychology to read as follows: When a series of dissimilar acts must be performed in quick succession, they are bound to *exercise an inhibitory effect upon one another.* But it may be added here that they affect one another unequally; and this leads us to examine our previous formulation of the problem anew.

As stated at the outset, the question was one of how we go about our task when we have two *different* kinds of impulses following one another in quick succession. But what constitutes their difference? To be sure, the different reaction to be performed according to the instructions governs the impulse. The *mere difference,* however, can have no significance for the reagent, except it be expressible in comparative terms. In other words, what is it that would determine the subject to act one way or another? The only basis that suggests itself as the determining factor is that of pleasantness and unpleasantness, or, taking it one step farther, that of *ease* and *difficulty,* taken either subjectively or objectively;[43] for in the conditions of the experiment, there was nothing else likely to act as a basis for the production of any marked feeling-tone, unless we assumed an extraordinary aesthetic discernment on the part of the subjects, something which was not brought out in any of the protocols. The difference in the color and shape of the stimuli, as well as the slight difference in the sound of the two keys, served only as guides and not as aesthetic factors.

We are now in a position to isolate and specify one phase of the problem of interference, and ask ourselves: Given a series of two sorts of impulses, the one governing a more difficult movement, the other an easier movement; which of the two movements will predominate?

The answer is, and this emphatically, that the easier movement of the two will be favored.[44] There are only a few isolated instances in which this did not occur—not more than a dozen revolutions out of nearly 3,000 revolutions—and even these sporadic cases were all but one or two explained in the introspective protocol. (One subject, LV for instance, explained, at the time, he had green after-images with the green dots; and as the green dots happened to represent the more difficult movements, he, on several occasions, emphasized the more difficult movement. Subject ML spoke once of putting most of his attention on the green stimuli. Another explanation of the seeming discrepancy lay in the fact that the subject wrongly associated the movement and would keep on making one reaction instead of the other throughout the revolution without becoming aware of his confusion).

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[43] It is important to distinguish between the degree of ease or difficulty as *supposed* by the subject (subjective) and the actual degree as revealed by the objective tests (objective).

[44] It will be found in the second part of this investigation that this result does not hold universally of the complex graphic movements. That difference and the grounds upon which it can be explained are significant.

The mutual, inhibitory effect was universal, and in the main manifested itself in omissions and confusion. The task was abbreviated, the more difficult movements suffering more than the easier. In subject LV, the interference did not give rise to omissions so much as to the execution of additional movements performed haphazardly. This anomaly will be discussed under individual differences.

Taking our first set of experiments, in which the double-down tap was to be compared with the double-side tap, we can point to the following tables:

TABLE I.

Totals for All Subjects Taken Collectively.

Type of Movement	OMISSIONS		ADDITIONS		No. of requisite reactions	No. of stimuli
	Double	Single	Double	Single		
Vertical	8.8%	5%	.55%	1.65%	40,542	20,271
Lateral	12.88%	7.06%	.37%	.92%	41,598	20,799

The difference between the results in the respective movements is striking in every respect. Not only is the emphasis on the vertical movement shown by the fewer omissions and less resorting to single reactions, which would indicate of course a shirking of half the work, but it is also noticeable in the tendency to add more vertical movements than lateral movements. We may say then that the favoring of the vertical movement manifests itself both in omitting fewer and adding more reactions in this type of movement than in the lateral. The additions are, of course, mistakes, but mistakes that reveal the dominant tendency to favor the one movement instead of the other.

The results of the individual subjects with regard to these two movements are even more clear-cut, for it will be seen that we can scarcely talk of any exceptions to the rule of omissions. Whatever exceptions do appear, are to be found only in several isolated cases, most of which are explained in the introspection (vide supra, p. 34). As for the tendency to add more vertical movements than lateral ones, subject RU is the only exception, but it must be explained that in this series of experiments the rate of speed suited him much more than the other subjects, and the task (both the vertical and lateral movements) for him was easy. Later, however, in the subsequent variations, the subjects were classified as to speed, and he was given a shorter period, which means, of course, a higher rate.

C. Translation of the Results.

These tables are not intended to prove merely that pressing a telegraph key *downwards* is a more favored movement than pressing it *sidewise,* nor should we be satisfied with drawing the conclusion that a downward movement is more easily made than a lateral movement. We rather set out with this conclusion, and though no tests were given to compare the technical difficulty of the vertical and lateral movements (the tests were started with the first variation), it would be easy to cite the results of such a comparison from the literature, even if we should feel disposed to discount the emphatic statements of the subjects to the effect that the lateral movement was more difficult than the vertical movement; and in this there was no difference of opinion, except as to the degree of difficulty. In experiments where the ring finger was used, J. C. Barnes found that "the lateral movement of the ring finger presented more

TABLE II.

Results for Individual Subjects in Per Cent.

Subject	Type of Movement	OMISSIONS		ADDITIONS	
		Double	Single	Double	Single
BU	Vertical	1.28	2.56	.68	.94
	Lateral	1.77	2.4	1.3	1.3
RO	Vertical	.87	3.6	.1	.37
	Lateral	2.02	6.2	.067	.3
FG	Vertical	3.46	7.07	.66	2.98
	Lateral	4.5	12.45	.125	2.16
GD	Vertical	7.08	2.34	1.45	2.74
	Lateral	13.43	5.45	.773	1.51
LE	Vertical	3.	7.5	1.07	4.9
	Lateral	15.2	13.9	.305	.915
ML	Vertical	6.95	9.15	.716	2.94
	Lateral	12.9	12.63	.4	1.38
TR	Vertical	16.12	1.18+	.04	.084
	Lateral	18.12	1.17+	.079	.04
TT	Vertical	13.18	15.6	.19	2.2
	Lateral	26.35	18.67	.076	.53
SR	Vertical	27.3	2.61	.168	*
	Lateral	30.85	1.07	*	*
		AVERAGE			
	Vertical	8.8	5.73	.56	1.9
	Lateral	13.9	8.21	.347	.903

difficulties than the vertical"[45] and points out rightly that the movement in the lateral direction is not so common as that in the vertical direction. This would hold especially for the forefinger which is so frequently used vertically in every-day activities—very rarely only in the horizontal plane.

The shunting of the difficult movement in favor of the easier one was not due to any perfunctory attitude on the part of the subjects. The writer who was at first inclined to suspect that not all subjects were "doing their best" soon found by actual trial that he had done the same thing, viz., emphasized the easier movement at the expense of the more difficult one.

It is interesting to compare our results with those of BAUCH, who had his subjects move their forefinger with the greatest possible speed from one point to any other of six points arranged in the form of a hexagon. He found that the most convenient (*bequemste*) movements were the most frequent,[46] and also that the most frequent movements were the most rapid.[47] In fact, most of his results point in one direction, viz., that the easier movement is the one likely to be favored as against the more difficult one. This one conclusion really forms the essence of most of his results when we reduce these to the lowest terms; for all his types of movements (centripetal and centrifugal, flexor and extensor, towards the median plane and away from it) resolve themselves into the more difficult and the easier type of reaction. Similarly KRAMER and MOSKIEWICZ are inclined to connect the slower with the more difficult movement and the easier with the more rapid movement.[48]

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[45] J. C. Barnes: Voluntary Isolation of Control in a Natural Muscle Group. *Psychological Review, Monograph Supplement* 93, p. 19.

* Subject SR showed no tendency to make additional movements. Only four such reactions were found in this series of records, and they were all on the vertical side.

These and other results of an analogous nature must not remain detached facts. They should be synthesized and studied in relation to one another, for they form a chain of results out of which it is possible to deduce or verify a fundamental principle that would possibly explain a number of phenomena hitherto observed in a more or less casual way.

D. *The Course of Least Exertion.*

The outstanding feature of the results both in the simple movement and the graphic experiments is the *universal tendency to move along the lines of least resistance.* So universal is this tendency and so numerous and far-reaching its manifestations that it would scarcely be presumptuous to formulate it into a law, once it is shown to operate in connection with other similar problems. For the present, however, let us content ourselves with regarding it as a *determining tendency,* but a determining tendency of a special kind.

The term "determining tendency" which has been in vogue since ACH published his experimental results on the will has come to connote a certain definite thing in psychology, and it would be quite unnecessary to substitute another term for it. But in reviewing our results, it becomes evident that we must distinguish between different kinds of determining tendencies which ACH probably found no occasion to do.

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[46] M. Bauch: Zur Gleichförmigkeit der Willenshandlungen in Fortschritte der Psychologie II, 1914, p. 367.

[47] *loc. cit.,* p. 354.

[48] Kramer and Moskiewicz: Beiträge zur Lehre von den Lage und Bewegungsempfindungen in Zt. für Psych. vol. 25, 1901, p. 121.

The determining tendencies that came up in ACH's work were those directly connected with the *Aufgabe*. We might expect different determining tendencies at work with different tasks. We should therefore be inclined to consider these as *subsidiary* determining tendencies depending upon some fundamental factor that is at the root of the several tendencies which it governs. This more fundamental director may be called then the *primary* or *dominant*[49] determining tendency. The *individual* determining tendencies responsible for individual differences we propose to call *"personal determinants,"* because they constitute collectively the complex known as personality.

Setting out with our primary determining tendency, viz., the course of least exertion, we shall see that all the other tendencies are either manifestations of the same principle or else modified by it.

The course of least exertion has been taken account of in more than one work, but so far as the writer is aware, it has not been treated experimentally, though it is possible to refer back some of the results obtained by SHERRINGTON and other British physiologists to this very principle. Some of these references will be cited later.

As early as 1894, the brilliant historian FERRERO tried to build up a sociological theory on the conclusion that "This law of least effort regulates the psychical activity of man."[50] This conclusion, in his case, is based on very thin evidence, often on bare assumptions and sweeping generalizations; yet we cannot afford on that account to lose sight of the suggestive idea that FERRERO has hit upon.

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[49] Titchener in describing the experiments of Külpe on abstraction uses the word "instinctively" in a peculiar connection when he says: "When no preliminary directions were given, the observers instinctively set themselves the easier tasks" (Text-Book of Psychology, p. 530). In view of that, our term "dominant determining tendency" should not be considered as too emphatic an expression of the fact.

[50] Guglielmo Ferrero: Les Lois Psychologiques du Symbolisme, p. 18.

In his last work[51] the late Professor Ribot has approached the subject with more insight than his younger contemporary, applying the "least effort" tendency in various connections in close conjunction with the law of parsimony or economy. The pith of his remarks is expressed in the following:

"Entre les deux, (i.e., the tendency towards the least effort and the law of economy) il y a un fond commun et identité de nature. On pourrait se risquer à dire que la tendance au moindre effort est un genre dont la loi d'économie est une espèce ou une variété. Ce qui les différencie c'est ceci: La tendance au moindre effort en général a sa fin en elle même, son idéal est le repos et ses résultats sont négatifs; la loi d'économie est un moyen pour la simplification au travail et ses résultats sont positifs."[52]

Now whatever the relation be between the law of economy and the tendency towards the least effort,[53] whether the former be a biological explanation of the latter or not, one thing seems pretty certain, and that is: a great many motor phenomena hitherto studied and reported as desultory facts should be regarded in the light of and referred back to that very tendency.

In our particular work there are scarcely any phenomena which could not be brought in line with, if not actually explained by, the course of least exertion. Thus it manifested itself in various forms. One of these was the tendency of the subjects to start in again on the easier reaction after a break in the work caused by the difficulty of keeping up with the rate—a result which is of great significance in educational psychology. Unfortunately, no figures are available for this result. The subjects were evidently unaware of this fact for some time; and in order to record all the cases where the subjects "came to" on the easier movement, it would have been necessary to take into account several side factors, so that the already great burden would have been doubled.

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[51] Th. Ribot: La Vie Inconsciente et les Mouvements.

[52] *loc. cit.*, p. 131-132.

[53] It seems more desirable to use the term "exertion" instead of "effort" which is sometimes employed in the sense of a feeling and is, at all events, not so objective a concept as exertion.

Suffice it to say that, in checking up some of the records occasionally with this purpose in view, the introspection on this point was confirmed: immediately after a gap in the record, the reaction for the easier movement followed.

THE LEVELLING PROCESS.

Closely allied with the foregoing is a group of phenomena that seem to point to a *compensatory* or equalizing process. It had been noticed during the computation of the records that omissions were followed on many occasions by additions, and *vice versa.* At first this was thought to be only accidental, at least not fraught with any special significance, for there is no reason to suppose that the subjects are immune from making mistakes in the number of taps, even in places where they could keep up with the stimuli. Thus instead of making, let us say, six reactions for the three green dots and four reactions for the two red crosses, they might make five each. In a case like this, one would be likely to suppose that we are dealing here merely with a rhythm phenomenon; and to be sure, rhythm plays no mean part in the interpretation of our experimental data, and instantly suggests itself as a form of expression of that which has been called here the primary determining tendency. But the compensation mistakes were not predominantly of this kind. In the first place, most of these occurred not within an immediate sequence of alternate stimuli, but within a sequence involving the *same kind of reaction,* in other words, an omission in the red was made up for by an addition in the following red, and likewise with the green. Between the two groups, however, the intervening group of the alternate color is very likely to have broken up the rhythm, supposing that this might have caused the repetition of the same number of taps. Secondly, by far the largest number of compensatory reactions did not involve an equal number of reactions. Thus frequently the relation was such as 5 and 3 instead of 6 and 2, or 4 and 3 instead of 2 and 4 reactions. In some cases the compensatory reactions took the form of simple *transpositions* as 4 and 2 instead of 2 and 4.

All these cases of compensations were marked on the records and counted up, in a separate column, beside the omissions and additions; and though their ratio is very small in general, it seemed altogether too striking to be disregarded.[54] It must be remembered also that in considering the ratio of such compensations, we must not compare them with the total number of reactions or even stimuli, but with the number of groups of stimuli. Under such circumstances, 6 or 7 cases of compensation in a record of 200 groups (about 500 stimuli), in the average, would suggest, especially when 75 per cent of the records show the occurrence of such "give and take," that we are dealing with a genuine phenomenon and not the result of mere chance (vide appendicem). If there was any doubt of it, the results in the writing experiments dispelled it entirely. There we have the unmistakable appearance of this phenomenon in a palpable form, as might be expected in the case of qualitative data. And for this reason, i.e., in order to subsume both classes of compensation under one general rubric, the term *levelling process* has been introduced.

Something analogous is reported in ACH's work.[55] In altering his instructions to the subjects after they had become accustomed to the previous instructions, it was found that frequently the subjects could not check themselves in time and gave the wrong reaction with the result that the succeeding reaction or reactions were bound to be correct, the failure producing greater strength of determination than otherwise.[56] In the actual result, i.e., the reaction of the correct (rhyming) syllable, the condition of the experiment naturally precludes a compensatory addition, such as our results indicate; but the greater effectiveness of the determination on the part of the subjects due to the previous failure may be evidenced by the lengthening of the reaction-time as well as by the introspective experience of the reagents.[57]

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[54] JUDD, MCALLISTER and STEELE (*Psychological Review, Monograph Supplements,* vol. VII. Analysis of Reaction Movements, 1905-6, p. 158) obtained something of this sort in simple reaction experiments, which they ascribe to rhythm of nervous action. "The impression is made upon one of a positive movement followed by a relaxation which in turn gives way to a rather sudden beginning of muscular contraction. The length of a single wave (from one crest to the next) is about 150 sigmas . . . These figures show that the wavy form of the line is not due to any gross mechanical causes, such as the subject's respiration. The waves represent a rhythmical unsteadiness of the subject's muscular tension."

It is for this very reason that we should regard them as connected with a compensatory tendency rather than with the periodic waves to be taken up in the next section.

[55] Ach: Ueber den Willensakt und das Temperament, pp. 272-274, pp. 51-53 and p. 49.

Curiously enough, in our experiments, the subjects were not aware of either making up for a previous failure or relaxing after an exaggerated reaction. At least the introspective protocols, with one solitary exception, do not reveal such knowledge. What is developed here is based wholly on the objective records.

The phenomenon of compensation seems to have as its antecedents not only the interference of the impulses corresponding to the different stimuli, but also a *conflict of* two determining tendencies. The primary determining tendency, we shall remember, is the course of least exertion. If this tendency had its own way with nothing to oppose it, we should expect to find a large number of omissions, but no additional reactions. But the determining tendency of carrying out the instructions to the very limit of one's ability is a hindering factor, which at times gains the upper hand and causes the subject to make a greater effort. In fact, it is not too much to say that even the making of errors is due to this very conflict. Were the primary tendency alone in operation, mistakes would be rare. Without putting on any special effort, the subject might react to only a very limited number of the stimuli and *react to those correctly*. With a certain type of subject, (the omitters, vide infra under individual differences), such was actually the case to a greater extent than with the other reagents. What really was responsible for the confusion was the seriousness with which the subjects accepted the exacting demand of the *Aufgabe* which, whether present in consciousness or not, undoubtedly determined the attitude of the subjects.

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[56] In Mellone and Drummond's Elements of Psychology (p. 171) we find an acute observation that takes the whole principle one step further than its scope in Ach's investigation. It is now applied to every-day life where "yielding . . . is sometimes more strengthening to character than resisting; for along with resistance there sometimes goes a dwelling on the pleasure we have denied ourselves which actually strengthens its hold over us and renders us more likely to succumb on the next occasion." The apt illustrations that are adduced in evidence of this conclusion need only be supplemented by the memories of our own experiences in this matter.

[57] The writer can also report that as a subject in reaction experiments, he has frequently noticed that an unusually long reaction-time will be followed immediately by a "keying up" which, it may be safely assumed, causes the next reaction to be unusually quick.

Another phenomenon that probably comes under the same head is a tendency on the part of the quick reagents to make additional taps while waiting for the next stimulus to appear. From the introspection, it would seem that these repetitions are not anticipatory of the next stimulus. Anticipations arise frequently when the rate is far too fast, but when the rate is too slow, i.e., when the dots are far apart, the quick reagents are apt to make mistakes by being too generous in their reactions. If the group consists of a single stimulus, it may be repeated; if there are two or three in the group, a couple more reactions than necessary might be tacked on. Now it is difficult to say whether the additions in the slow part are a sort of atonement for the many omissions in the more accelerated portion of the work, or whether it belongs to *the tendency to continue the same process* which was recorded so frequently in the introspective protocols. Should the cause of these additional taps lie in the latter tendency, then it is clear that we have in this phenomenon a noteworthy instance of inertia. But whereas we can readily understand why continuing the same movement is objectively preferable to making a new movement, it is not so easy to explain why the subjects should keep on adding unnecessary taps instead of resting the fingers until the next stimulus would appear. As there were only four subjects for whom *any* part of the task was so easy that they could afford to wait here and there during the slow parts (farther apart stimuli) for the next stimulus, the data are of course very scant, but even these comparatively few cases warrant the conclusion that *for every individual reagent there is an optimal rate above which and below which he is apt* *to make mistakes*—in the latter case, both mistakes of commission and mistakes of omission; in the former case, mistakes of commission alone. In other words, make the task too easy and you are putting a stumbling-block in the way of the reagent; for from the point of view of accuracy, it is just as wrong to make six reactions, as it is to make only two reactions, instead of four.

RHYTHMIC ACTIVITY.

Under *rhythm* we have a group of phenomena, which, though not all occurring with the same subject, appear separately in the records of the various subjects and point to some underlying factor that determines the reactions of different subjects in different ways.

That this should be the case is not surprising, when we consider to what an extent the working of the physiological mechanism is dominated by rhythm. Indeed the phenomenon of rhythm[58] and periodicity is so universal that it has been incorporated as a vital element in many an all-embracing theory of the universe. The influence of rhythm on work has been studied extensively since the appearance of BUECHER's "Arbeit und Rhythmus," and recent physiological investigations (PIPER, J. LOEB, BERGER, SHERRINGTON, GRAHAM BROWN, MARTIN, and others) have only served to emphasize the rôle of rhythm in our psychophysical make-up.

In our own work, the rhythmic tendency expressed itself (a) in a seemingly automatic repetition of previous reactions (3 or 4 groups in succession with the same number of reactions), (b) repetition of the same mistakes in succeeding revolutions, (c) creating a spontaneous rhythm regardless of the stimuli, (d) stopping on odd number of reactions (it will be recalled that every stimulus represented two reactions on the key). These well-marked phenomena, apart from the introspective accounts which will be given in the next chapter, cannot but call for an explanation only on the basis of rhythm.

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[58] The writer is in full agreement with M. Keiver Smith (*Rhythmus und Arbeit* in *Philosophische Studien,* 1900, Vol. XVI, p. 300) who insists on the distinction between rhythm and periodicity. The distinction, however, does not rest on the difference between "bewusste Zustände' and "unbewusste Verhältnisse," or even between the organic and the inorganic world' as she seems to suppose, but rather depends on the time interval between the occurrences. Thus, pulse beats are a rhythmic phenomenon, while the menses are periodic occurrences. We must not identify rhythm with the perception of rhythm, though we have to depend on the latter for our criterion of a rhythmic phenomenon. Periodicity, on the other hand, cannot be told except through some external indications or by calculation.

The entire mechanism of rhythm has not been adequately explained. *Féré* who has made an interesting contribution to the psychophysics of work, simply explains the fact by saying that rhythmic activities involve less effort.

> "La répetition de l'acte volontaire dans les mêmes conditions le rend plus facile á exécuter en atténuant l'effort nécessaire par le travail mental. C'est cette atténuation de l'effort intellectuel réalisé par l'habitude qui est la base physiologique de la routine si difficile à déraciner.
>
> "Les groupements simples des mouvements, qui en favorisent la représentation préalable, augmentent le travail."[58a]

This sounds as if rhythmic activity were one mode of realizing the tendency towards the least exertion. We can understand accordingly in this light the finding of TRÈVES that in work on the ergograph, there will establish itself a rhythm representing the maximal frequency compatible with the production of constant work.[59]

Such observations,[60] afford us the *raison d'être* of rhythmic activity, but do not supply the information we are seeking, viz., the *genesis* of rhythm.

Miss Keiver Smith claims that the origin of rhythm is physiological, but the application of it to the regulation of work involves a psychical influence, for it is a means of renewing the will impulse and the attention.[61] This again is a statement regarding rhythm as a condition and not as an effect. Possibly the flagging of attention has something to do with the repetition of mistakes at certain intervals, but in does not explain the automatic repetition of the number of previous reactions, nor does it throw any light on the occurrence of such a series as 5, 3, 1, 3, 5, 7 instead of 6, 4, 2, 2, 3.

[58a] Ch. Féré: Travail et Plaisir, p. p2.

[59] Z. Trèves, Sur les conditions qui déterminent le rhythme spontané dans le travail ergographique volontaire. 5 me. Congrès International de Physiologie, 1901, cited by Ch. Féré *loc. cit.*, p. 20.

[60] *Cf.* also, Davis who cites two other investigations in connection with his own findings of rhythm in tapping, Reserches in Cross--Education in Studies Yale Psychological Laboratory, p. 15.

[61] M. Keiver Smith: Rhythmus und Arbeit, p. 394.

It should be said also that all the reagents were subject to one form of rhythm or another. To note the most typical instances, subjects T R, L Z, S R never showed a tendency to make single reactions, and very rarely repeated previous mistakes, but they, more than any others, perceived the stimuli as groups and ignored the single dots or crosses. LE, on the other hand, perceived the stimuli separately, but followed out a certain rhythmic plan in reaction, favoring the odd number. G D was free from the latter tendency, but would repeat mistakes occasionally. R U did not show any marked development of the other tendencies, but in some parts of his work, he lapsed into a rhythm that he had picked up spontaneously, and that, he thought, had been suggested by his work in former weeks.

It may be that these facts have only a remote bearing upon one another, that the absence of rhythm in one form is not coupled with its appearance in another form, it may even be doubted whether the various phenomena described as rhythmical issue from a common root—that they are suggestive, however, of a rhythmic process which is dependent on the conjuncture of determining tendencies including personal determinants can scarcely be denied. This, of course, does not necessarily mean that the rhythmic processes are due to the conditions of our experiments. After the evidence that has been accumulating on all sorts of physiological and psychophysical rhythms from the contractions of the muscle fibres of Medusa,[62] and isolated strips of heart muscle,[63] to the most concentrated type of attention, it appears quite certain that any simple task,[64] would be attended by some rhythm phenomenon, as TRÈVES has, as a matter of fact, demonstrated some years ago (*vide supra*). Nevertheless, it is quite safe to surmise that the more complex the conditions, the more devious will be the rhythm, if for no other reason, because of the many factors that are set into play, often working at cross-purposes. Thus the regular breathing rhythm takes on a different form in certain pathological cases when the respiratory movements occur in groups separated by apnoeic pauses. As CHEYNE and STOKES described it, there is first an increase in the respiratory movements until the maximum is reached and then there is a falling off until they stop entirely, and EYSTER showed that there is a similar rhythmic wave of blood pressure under those conditions.[65]

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[62] J. Loeb: Comparative Physiology of the Brain, p. 16 ff.

[63] E. G. Martin: Amer. Journal of Physiology, vol. II, 1904, p. 103 ff.

[64] For rhythm in reading, cf. W. F. Dearborn: Psychology of Reading, p. 118 (Archives of Phil. Psych. and Scientific Methods, no. 4) and Huey: The Psychology and Pedagogy of Reading, p. 175.

Whatever sort of rhythmic phenomenon we might be studying, be it ever so complex, should be examined in the light of more elemental rhythms. The course here does not differ from the procedure in other and, sometimes, more complex processes. This attitude is instanced in SHERRINGTON'S asking

> "How there are developed from such minutely oscillatory nervous discharges those coarser rhythmic actions with periods recurring once in 3 secs., as in breathing, or 1 in a sec., as in the step, or 4 times a sec., as in the scratch reflex?"[66]

The tentative answer that SHERRINGTON gives to the question he has raised bears closely on what has been said above about the complexity of conditions in relation to the resulting rhythm.

> "The suggestion has often been made," SHERRINGTON says further, "that such rhythmic nervous actions are the result of the concurrent action of two opposed nervous forces, the outcome of a constant opposition or resistance acting against a constantly discharging nervous activity."

And it may be added that there is nothing in the whole article to indicate that he finds fault with this suggestion. Applying this tentative explanation to the work described here, we may say that while rhythmic phenomena are to be expected almost in any task,[67] the *particular kinds of rhythmic phenomena* disclosed in our records are due to the two opposing series of impulses, in other words, due to interference. We may even go further and hold that wherever we find rhythmic processes that suggest those mentioned earlier in this study, there is a likelihood that the result is due to interference conditions. Thus in SCHUYLER'S work on the acquisition of skill in typewriting, a reference to rhythm is contained in the statement that

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[65] Howell: Text Book of Physiology, 2nd ed., p. 654.

[66] Sherrington: Nervous Rhythm Arising from Rivalry of Antagonistic Reflexes. Proceedings Royal Society, London, 1913, vol. 86, Series B, p. 235.

[67] *Cf.* the periodic fluctuation tendency in Berger's tapping experiments which were mentioned in the survey of literature (*vide supra*, p. 17).

"In the curve of errors that which attracts attention is the remarkable persistence and regularity of the mistakes."[68]

Book also talks of "regular and irregular fluctuations"[69] explaining the former on the basis of the ANTRIEB and ANREGUNG or increase and relaxation of attention. In both of these investigations, the interference processes may have had much to do with the occurrence of periodic fluctuations. We shall have occasion to touch upon this subject again in discussing the results of the writing experiments.

THE GROUPING OF MISTAKES.

Marked off from the foregoing, though at first bush seemingly connected with it, is the tendency to continue going wrong once a start is made in that direction. One mistake would lead to utter confusion for a series of stimuli, until the subject, either by pausing or otherwise managing to gain control over the situation, is again able to proceed smoothly with his work. It should be made clear that "mistakes" is not used in a sense that would include omissions. The attitude involved in making a mistake seems to be a different one from that of omission; and if we were to adopt a term employed by ACH[70] we should be inclined to call the former a *"nichtintentionale Fehlreaktion,"* and the latter an *"intentionale Fehlreaktion,"* the degree of the difference varying with the different subjects.

This tendency of lapsing into a series of errors has rarely been alluded to in the literature, as YOAKUM observes,[71] but the occurrence seems to be very common. Perhaps its very naturalness is the cause of its not receiving more publicity at the hands of investigators. Certainly it is easier to explain the clustering of mistakes than to find the cause of the first mistake made. In popular lore, there is many a saying among a number of peoples to the effect that one mistake (Sin, crime, etc.) brings on another. If we stop to analyse some of the ethical cases in which this maxim is true, we shall probably find that the situation, though of vastly greater consequence, is similar to that where the subject is required to perform a difficult experimental task.

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[68] E. J. Swift and W. Schuyler: *Psych. Bulletin*, vol. IV, 1907, p. 310.

[69] Book: The Psychology of Skill, p. 120 and 123-127.

[70] Ach: Ueber den Willensakt und das Temperament, p. 270,*cf.* also p. 243 and 259.

[71] Yoakum: An Experimental Study of Fatigue. *Psychological Review, Monograph Supplements* 26, p. 65.

In reporting the grouping of errors, YOAKUM states that he was

> "Gratified to note that the same general phenomenon had been found in connection with some practice tests made on the typewriter by Mr. William Schuyler."[72]

It is hardly likely that a tendency of this sort would be so utterly ignored,[73] and even if it is mentioned rarely, it comes up in the literature sometimes in a somewhat different connection. BOOK, for instance, says

> "A third fact revealed by our data was, that when the fluctuations in attention and effort above described were noticed by the learner, they were almost invariably followed by lapses in the efficiency of the effort put forth."[74]

What happens is just this: in a critical moment a wrong reaction is made. The subject notices the mistake, and this puts him out of gear. The mind becomes more and more befogged until a sufficient period has elapsed for recovery.[75] This half-dazed state which is described in the introspection will often give rise to a whole series of random or blind reactions.

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[72] Yoakum: *loc. cit.*

[73] ACH does not report the occurrence of errors in groups, but we must remember that his conditions would not be favorable for such a phenomenon to come to light, as the task with his subjects was not a continuous one but discrete, so that there is really time between the single experiments for the subjects to pick up through sheer determination, even when as a result of several failures there developed a "Zustand der Verzweiflung mit einer Entsagung auf weiteres aktives Eingreifen" (Ach, *loc. cit.*, p. 273).

[74] Book: Psychology of Skill, p. 132.

[75] Mr. O. V. FRY who has been working on railway tests in the Harvard Psychological Laboratory noticed the same tendency on the part of the subjects in manipulating the throttle (results unpublished). He furthermore

RANDOM REACTIONS.

The reactions given by subjects during the state of utter confusion are called random reactions. In reality they are not responses at all. The subject taps the keys without reference to the stimuli, but simply alternates first one movement for a time and then another, continuing so until he is able to make a fresh start on some stimulus he has fixed his attention upon. This is one way, in fact the only way, that those particular subjects who lapse into a state of confusion have of carrying out the instructions. This random tapping is not merely a reversal, i.e., where the movement and the stimulus have become wrongly associated, and the subject is reacting to the red stimulus with the movement representing the green stimulus, and *vice versa*. An examination of the records shows no correspondence whatever between the reactions and the stimuli. A single reversal, however, may have brought about the whole lapse.

In closing the chapter on the general results, it may be stated that these hold for all the series of simple movement experiments. We have, however, before us a body of data that bear on inter-serial and intra-serial relations. We may ask ourselves, for instance, how the results of one variation compare with those of another or whether the degree of interference in one revolution is more marked than in another. These and other questions of this sort which may suggest themselves are treated below under the caption of specific results.

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declares that this situation is responsible for many a disaster, for frequently an engineer will run past several signals without taking the necessary precautions that the signals were intended to convey.

CHAPTER VI

SPECIFIC RESULTS.

In the last chapter we have become acquainted with a number of facts in connection with interference, chief among which stands out the result that the easier of two movements is apt to be emphasized under pressure. From the two tables giving the results for the vertical and lateral movements, we have seen that there was a strong tendency to favor the vertical (downward) movements in every way. Not only were there fewer omissions here, but more additions, i.e., superfluous movements.

Let us now examine the results of the other series, all of which, as has already been intimated, indicate the same general tendency.

In the second series, it will be remembered, two fingers were employed to execute the two different movements, viz., the forefinger and the medius (of the left hand, as in the first series). Both movements were now downward taps on the keys. Much time need not be lost on finding out which of the two movements is the easier, since from common experience we know the middle finger to be both the slower and the more difficult of the two to manipulate separately. The explanation is not far to seek. The close relation between the two fingers affects the medius more than the forefinger which, owing to practice in the separate use of its muscles, has undergone some modification to the extent that it is not as inseparably bound up with the grasping reflex as are the other three fingers. In other words, the forefinger, being the less dependent of the two, in its relation with the middle finger, offers less inhibition when moved alone,[76] and is, therefore, other things equal, the easier finger to make a movement with. In the 30 secs. tests that were given for the sake of comparing the technical difficulty of the two different movements, the larger number of reactions with the forefinger as compared with those where the medius was used proved that one is safe in assuming that the forefinger reaction would be technically easier than the medius reaction. This should be borne in mind in examining the next two tables.

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[76] *Cf.* H. S. LANGFELD: Facilitation and Inhibition of Motor Impulses. *Psych. Review,* vol. XXII, 1915, p. 456.

TABLE III

Totals for All Subjects Taken Collectively. (Series II.)

Type of Movement	OMISSIONS		ADDITIONS		No. of requisite reactions	No. of stimuli
	Double	Single	Double	Single		
Forefinger	11.7%	4.6%	1.8 %	3.6+%	49,800	24,900
Middle finger	16.8%	6. %	.75%	2.3%	56,352	28,176

TABLE IV.

Results for Individual Subjects in Per Cent. (Series II.)

Subject	Type of Movement	OMISSIONS		ADDITIONS		30 secs. test
		Double	Single	Double	Single	
LV	Forefinger					
	Forefinger	1.75	1.65	20.86	28.7	$68\,^{5}/_{2}$ a
	Mid. finger	4.28	2.62	6.45	22.09	$66\,^{2}/_{2}$
RO	Forefinger	5.58	2.83	.31	8.25	83
	Mid. finger	8.42	5.26	.14	.32	$75\,^{2}/_{2}$
RU	Forefinger	7.3	2.3	.42	1.22	95
	Mid. finger	11.4	4.	.47	.64	$91\,^{1}/_{2}$
FG	Forefinger	4.37	5.82	.41	3.92	78
	Mid. finger	6.16	11.26	.42	1.77	$69\,^{1}/_{2}$
GD	Forefinger	9.	2.3	3.	5.1	unavailable
	Mid. finger	13.	3.45	.04	3.6	
LE	Forefinger	6.1	3.35	2.28	4.11	58
	Mid. finger	13.	5.77	1.07	2.42	$66\,^{1}/_{2}$ b
LO	Forefinger	8.53	5.	1.37	2.64	$72\,^{1}/_{2}$
	Mid. finger	13.13	5.8	.74	1.3	67
LL	Forefinger	10.	10.81	.3	2.3	$64\,^{2}/_{2}$
	Mid. finger	16.58	9.77	.13	1.04	$48\,^{19}/_{2}$
TT	Forefinger	10.34	12.25	1.40	6.72	unavailable
	Mid. finger	18.9	16.	1.32	2.84	
ML	Forefinger	15.5	7.86	.13	.57	$67\,^{1}/_{2}$
	Mid. finger	21.9	6.71	.12	.25	63
SR	Forefinger	24.9	1.41	.24	.55	$78\,^{5}/_{2}$ c
	Mid. finger	29.6	2.56	.18	.3	$71\,^{1}/_{2}$
LZ	Forefinger	29.	2.8	.05	.25	$60\,^{6}/_{2}$
	Mid. finger	38.	3.84	none	none	64
			Average			
	Forefinger	11.03	4.86	2.56	4.74	72.5
	Mid. finger	16.19	5.58	.92	3.04	70.

In table III we note again that the easier movement is favored both by the smaller number of omissions and the greater number of additions. This tendency is consistently exhibited throughout the second series, sporadic cases of emphasis on the more difficult movement having already been explained as due to extraneous factors (after-images with a particular color, for instance) and amply accounted for in the introspection of the subjects.

That the results of the individual subjects present the same general phenomenon will readily be seen from the preceding table.

Remarks on the 30 secs test. (Table IV)

(a) The instructions were to tap in pairs just as had been done in the regular experiments; hence, the single taps were counted separately.

(b) The writer has not been able to explain this seeming anomaly on the part of LE. The computation of the test record was made long after there was any opportunity of investigating the discrepancy.

(c) There is really no comparison here, because subject SR tapped in pairs only with the forefinger. The tapping with the middle finger was done continuously, hence the *Aufgabe* was not kept the same for both. There was a great deal more deliberateness with the forefinger tapping as shown by the regularity of the pairs.

Comparison of Series I and II.

Judging from the total percentage of both omissions and additions in the two series respectively, one would be inclined to say off-hand that inhibition (and confusion) is more marked in the two finger (forefinger and middle finger) combination than in the vertical-lateral (forefinger alone) arrangement. In all probability that is so, though the fact could not be actually demonstrated, seeing that several subjects dropped out just after the beginning of the second series, and were replaced by others. The new subjects, LZ and LV, must have affected the average materially, though in opposite directions. For this reason, however, it might be said that the one offset the other. RO and RU show a great increase in omissions. In part this is to be explained by the fact that the period had been shortened for them from 33 secs. to 28 secs. Yet the slight increase of rate alone could not have been responsible for the four-fold increase of double omissions in the case of RO and the six-fold increase in the case of RU. Besides, several other subjects give evidence of a similar increase, in spite of the practice that they have had. The two slowest subjects, TT and SR, however, on the contrary, show a marked improvement, which is greater for the more difficult movement, though the easier is still the one to be emphasized, but the gap now is not so great as it was in the first series.

Granted that there is, all things considered, more inhibition with the two movements of the second series, we must guard against assuming that the forefinger reaction of the latter is the same as that in the former series. As far as the instructions are concerned, they were all the same, and the subjects might have thought that, as in the first series, they were performing a vertical downward movement with the forefinger, which is true enough, but we must not lose sight of the circumstance that while in the first series the forefinger was the only finger outstretched, the rest of the hand being closed, the subjects had, in the present series, two neighboring fingers outstretched, *mutually inhibiting each other all the while.* This is an important point to take cognizance of; for it emphasizes the need of studying two given movements not only in relation to, but also as *actual functions* of each other. Before we can ascertain the relation, it *is necessary to study the one in the light of the other.* When one finger performs two different movements, the dependence is not so great as when two different (and adjacent) fingers perform each a similar movement. Hence it would not be safe to conclude that because the second series presents a greater degree of inhibition, and the vertical movement is common to both series, therefore the downward movement for the medius is responsible for the added difficulty and is more susceptible to interference than the lateral movement of the forefinger. What mars the validity of this argument is the assumption that the downward forefinger movement is common to both series. In reality, this movement is more hampered in the second series, and this seems to be a contributing factor in the increase of inhibition.

In passing to the results of the third series, we must again take this reciprocal inhibitory effect of the two fingers into consideration before we can arrive at any conclusion as regards the inhibitive coefficient of each finger separately.

Series III. (Middle finger and ring finger)

The third series offers the most irregular results, irregular in the sense that it does not bear out our expectations. In the first place, we should suppose that the set of movements involving the middle finger and the ring finger would be more difficult to carry out than those performed by the forefinger and the middle finger. Our results show there is less inhibition here, and only slightly more than in the first series, as will be seen from the following table in comparison with tables I and II.

TABLE V.

Totals for All Subjects. (Series III.)

Type of Movement	OMISSIONS		ADDITIONS		No. of requisite reactions	No. of stimuli
	Double	Single	Double	Single		
Middle finger	8.76%	5.004%	.723%	2.03 %	35,688	17,844
Ring finger	14.674%	7.655%	.294%	.942%	40,152	20,076

The deviation from what might have been expected is still more noticeable when we come to examine the individual percentages. What stands out particularly is the curious shift of places in the efficiency order of several of the subjects, showing clearly that there are vast individual differences in connection with the movement of the two different fingers. There is no doubt that improvement in general plays a great part here. This can be seen by comparing the 30 secs. tests in the second and third series (vide tables IV-VI). Meanwhile let us glance for a moment at the individual percentages of omissions and additons in the third series.

TABLE VI.

Results for Individual Subjects in Per Cent. (Series III.)

Subject	Type of Movement	OMISSIONS		ADDITIONS		30 secs. test
	Downward	Double	Single	Double	Single	
LV	Mid. finger Ring finger	1.59 2.81	2.1 4.46	1.75 .69	6.12 2.85	81 4/2 73 8/2
RO*	Mid. finger Ring finger	3.75 4.88	3.96 3.91	.46 .046	.36 .55	83 1/2 77
RU*	Mid. finger Ring finger	8.89 14.54	1.23 2.29	.25 .13	.72 .5	94 88 1/2
LO	Mid. finger Ring finger	4.84 13.48	3.56 3.68	3.41 1.46	3.56 1.52	78 1/2 67 1/2
FG	Mid. finger Ring finger	4.99 8.51	10.39 12.984	.823 .414	2.52 1.24	80 4/2 84
LL	Mid. finger Ring finger	5.19 11.51	11.72 13.58	.31 .092	2.21 1.19	66 57 1/2
LE	Mid. finger Ring finger	11.25 19.73	3.846 11.15	.64 .12	2.63 1.28	67 61 1/2
LZ	Mid. finger Ring finger	13.52 22.375	2.42 7.91	.1 .046	1.8 .5	73 1/2 72
ML	Mid. finger Ring finger	11.67 22.34	7.45 11.41	none none	.256 .092	66 62
SR	Mid. finger Ring finger	26.05 31.35	1.76 4.13	none .18	.21 .06	78 1/2 67 1/2
			Average			
	Mid. finger Ring finger	9.17 15.15	4.84 7.45	.77 .31	2.03 .97	77.8 73.2

In this series subjects LO and LZ give evidence of most marked improvement, while subjects LE and ML, on the other hand, present a drop in the work. The other changes are slight. It will also be seen that LV now makes far fewer additional taps than in the former series.

Series IV.

The most difficult set of movements was by far that of the fourth series in which the subjects made an upward movement with the nail part of the forefinger (dorsal or posterior) and a downward movement in the usual way, i.e., with the tip of the same finger (volar or anterior). These two types of movement have also been referred to previously as extensor and flexor reactions respectively.

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* It will be remembered that subjects RO and RU were given 28 secs. per revolution, while all the rest had 33 secs. per revolution.

The upward movement after a very short period became painfully fatiguing. Hence the high percentage of omissions in this series as shown by the following table.

TABLE VII.

Totals for All Subjects. (Series IV).

Type of Movement	OMISSIONS		ADDITIONS		No. of requisite reactions	No. of stimuli
	Double	Single	Double	Single		
Forefinger						
Flexor	12.345%	8.7%	.682%	1.34%	27,168	13,584
Extensor	21.98 %	8.95%	.276%	1. %	34,728	17,364

In the individual results we note another change in order. Subject FG is not only the least affected by the introduction of the upward movement, but is the only one for whom the present series seemed to be markedly easier than the previous series. A slight gain is also shown by ML. With the exception of FG, the quick reagents proved to be relatively much more affected by the increased difficulty than the slow reagents (cf. RC, RU and LV). There is also with them a relatively greater divergence between the two movements.

The most striking anomaly in these results is presented by LL who, both in the regular experiments and the 30 secs. test, slightly favors the extensor movement. His playing the violin does not seem to have any connection with this result, as there were other instrumentalists among the subjects, but none besides LL gave evidence of this remarkable deviation.

The relation between flexor and extensor movements had already been taken up in several investigations, and it is generally agreed that the former of the two movements is the more

TABLE VIII.

Results for Individual Subjects in Per Cent. (Series IV.)

Subject	Type of Movement Forefinger	OMISSIONS		ADDITIONS		30 secs. test
		Double	Single	Double	Single	
FG	Flexor	2.94	11.55	.56	1.75	$80\,^{1}/_{2}$
	Extensor	6.98	14.3	.56	3.04	70
LV	Flexor	5.04	6.03	1.97	4.93	88
	Extensor	11.71	9.35	.709	4.	65
RU	Flexor	17.86	3.78	.14	.91	$90\,^{1}/_{2}$
	Extensor	22.18	3.66	.45	1.07	74
RO	Flexor	15.12	5.81	.21	.21	$84\,^{1}/_{2}$
	Extensor	21.56	11.93	none	.56	$67\,^{3}/_{2}$
LO	Flexor	6.58	4.9	3.64	4.06	68
	Extensor	23.93	7.48	1.12	1.18	$65\,^{1}/_{2}$
ML	Flexor	10.38	4.88	none	.72	$75\,^{1}/_{2}$
	Extensor	24.26	6.62	.04	.16	$62\,^{1}/_{2}$
LE	Flexor	13.65	13.65	.35	1.19	78
	Extensor	20.6	11.31	none	.22	56
LL	Flexor	19.88	23.66	none	.21	$50\,^{3}/_{2}$
	Extensor	22.97	17.45	none	.337	$53\,^{1}/_{2}$
SR	Flexor	29.22	5.82	none	.11	$86\,^{2}/_{2}$
	Extensor	31.33	4.08	none	.08	64
LZ	Flexor	21.14	4.55	.14	.28	unavailable
	Extensor	33.55	27.	none	.61	
			Average			
	Flexor	14.18	8.46	.7	1.43	78.44
	Extensor	21.9	11.31	.28	1.12	64.34

favored, and, more favored because the easier and the more rapid to perform.

CAMERER,[77] who seems to have been the first to compare these two movements experimentally, was led to the conclûsion that extension is easier than flexion, and BAUCH[78] is at a loss to square this conclusion with his own results which indicate a perfect correlation between the more favored (*bevorzugt*) and the easier (*bequemer*) movement. In fairness to CAMERER it ought to be said that BAUCH overlooks the conditions of the original experiment. If CAMERER had compared flexor and extensor movements in a vertical plane, and, what is even more important, of the fingers or wrist, (forearm), there can be no doubt that the results would tally with those of other investigators, including BAUCH. The movements, however, with which CAMERER was concerned were in the horizontal plane, as is plain from his description in his article.[79] In view of this, the characteristic feature of the opposition is not that between flexion and extension, but rather between centripetality and centrifugality; and even the latter distinction would have to be further qualified, as ordinarily the centripetal movement is affirmed to be easier than that away from the body (centrifugal).

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[77] W. Camerer: Über den Zeitlichen Verlauf d. Willensbewegungen, Zt. für Biologie, vol. XLVII, N. S. vol. XXIX, 1906, p. 272.

[78] M. Bauch: Zur Gleichförmigkeit der Willenshandlungen, Fortschritte der Psych. etc. vol. II, 1914, p. 366.

All this goes to prove how important it is to specify, in every case, if not the anatomical mechanism involved in a given movement, at least the position of the limb performing the movement as well as the plane and the direction in which the movement is made. Flexion and extension of the arm involving the biceps and triceps muscles are certainly not in the same class with the flexion and extension of the hand or the individual fingers where the ulnar flexor and extensor muscles as well as their tendons are involved. For this reason, it would not be safe to apply a conclusion drawn for a given set of flexor and extensor movements to all such antagonistic sets we can think of; and while possibly CAMERER's designation of the antagonism was a misnomer, BAUCH was not warranted in supposing that the former's results would make the easier movement the less favored.[80]

Besides BAUCH, who has already been mentioned as identifying flexion with the easier movement and extension with the more difficult, GAULT[81] has found that flexion is the more rapid of the two. Here, too, the movements seem to be in the horizontal plane, but the upper arm is not used to the same extent as in CAMERER's experiments.

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[79] *loc. cit.*

[80] Bauch's mode of reasoning, when stated in succint form, is this: Several investigators, including myself, have found flexions more favored than extensions; (2) but Camerer has found flexions more difficult (unbequem) than extensions to perform; hence, (3) the more difficult movement is the more favored movement. If we took the trouble to arrange this bit of inference, formally, we should probably be able to detect in these three propositions the fallacy of undistributed middle, or perhaps rather ambiguous middle, giving us four terms instead of three. Bauch's reference is to Camerer's dissertation of 1866, and not the article of half a century later.

[81] R. H. Gault: On Conditions Affecting the Minimal Rate of Voluntary Extensor and Flexor Movements of the Right Arm. *American Journal of Psychology,* pp. 370, 383.

There seems, at first sight, to be a wide divergence in the percentage of the omissions for the two movements in the fourth series, and that is really what we should have expected considering that the grasping reflex and the natural semi-flexed position of the fingers would tend to strengthen the flexor mechanism, while, on the other hand, the fingers are comparatively seldom held in a rigidly outstretched position. Yet if we examine the results of the various series, we shall find that both in the percentile totals and percentile averages of omissions and additions, taken together, there is greater approximation between the two movements of the fourth series than for any of the other series.

How can we account for this fact? Only one form of explanation suggests itself to us and that is to assume that the high degree of mutual opposition between the flexor and extensor movements has been reduced considerably as a result of practice. The improvement, accruing from practice would consequently not only affect the motor ability of the fingers, and reduce the actual number of omissions (compare second and third series), but would also tend to overcome the strength of the dominant determining tendency and reënforce the determining tendencies touched off by the instructions. In other words, the easier movement would not, relatively speaking, be emphasized so much as originally. A tendency towards such approximation would indicate improvement in the direction of greater resistance.

In order to facilitate comparison of the various results, a table is here appended giving the totals and averages for all the four series.

From the preceding table it is clear that there is a general tendency for an increment in the difficulty of the one movement to affect the other more or less proportionally; in other words, *increase the difficulty of either of two movements,* and the result is that *both movements are made more* difficult, i.e., a redistribution of inhibition values will take place.

TABLE IX.

Comparison of All the Series.

Type of Movement	OMISSIONS		ADDITIONS		Inhibition Ratio[82]
	Double	Single	Double	Single	
Forefinger		SERIES I. *Totals for All Subjects.*			
Vertical	8.8%	5.%	.55%	1.65%	
Lateral	12.8%	7.06%	.37%	.92%	58.7%
		Average			
Vertical	8.8%	5.73%	.56%	1.9%	
Lateral	13.9%	8.21%	.347%	.903%	59.15%
Downward		SERIES II. *Totals for All Subjects.*			
Forefinger	11.7%	4.6%	1.8%	3.6%	
Mid. finger	16.8%	6.%	.75%	2.3%	59.1%
		Average			
Forefinger	11.03%	4.86%	2.56%	4.74%	
Mid. finger	16.19%	5.58%	.92%	3.04%	51.57%
Downward		SERIES III. *Totals for All Subjects.*			
Mid. finger	8.76%	5.%	.723%	2.03%	
Ring finger	14.67%	7.65%	.294%	.94%	52.9%
		Average			
Mid. finger	9.17%	4.84%	.77%	2.03%	
Ring finger	15.15%	7.45%	.31%	.97%	54.23%
Forefinger		SERIES IV. *Totals for All Subjects.*			
Flexor	12.34%	8.7%	.66%	1.34%	
Extensor	21.98%	8.95%	.27%	1.%	59.81%
		Average			
Flexor	14.18%	8.46%	.7%	1.43%	
Extensor	21.9%	11.31%	.28%	1.12%	63.61%

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[82] The inhibition ratio was obtained by dividing the results of the more difficult movement into those of the easier after making due allowance for the additions and giving half values to the single reactions of both the omissions and additions. The formula may be stated thus

$$\frac{D.O. + \frac{S.O.}{2} - D.A. - \frac{S.A.}{2} \quad \text{(easy)}}{D.O. + \frac{S.O.}{2} - D.A. - \frac{S.A.}{2} \quad \text{(difficult)}}$$

D.O. = double omissions
S.O. = single omissions
D.A. = double additions
S.A. = single additions

Converting the omissions to positive values and adding thereto the additions would of course yield a much higher ratio, as this would be computed in terms of *achievement;* but the *order* of the ratios is not affected in either

From the inhibition ratio values, we may infer that the greater the practice the more chance is there for individual variation. For in the first series there is scarcely any difference between the percentile total and percentile average. The discrepancy between the two in the second series is due, in all probability, to the fact that several new subjects had come into the experiment during this series. We should say that this circumstance brought about a greater variation from the mean. The difference is greatly reduced in the third series, but yet, as the table shows, greater than for the first series, while in the fourth series, there is another slight rise. The effect of unequal practice, then, is the only thing we can think of to account for this regular phenomenon.

TABLE X.

Showing Facility of Different Finger Movements.

	Series I		Series II		Series III		Series IV	
	Forefinger		vertical		downward		Forefinger	
Double reactions per 30 seconds	Vertical downward	Lateral centripetal	f. f.	m. f.	m. f.	r. f.	flexor	extensor
	Tests not given		72.5	70	77.8	73.2	78.44	64.34

Just what the facility ratios are of the different movements to one another cannot be told from the data in hand, because we don't know how much allowance to make for practice, but we can easily present the different movements in the order of their facility (i.e., objective ease) from the last two tables. In this scale we can also find a place for the lateral movement (though there is no separate test for it) by comparing first the inhibition results of the different series, and then the individual finger tests. The order accordingly would be as follows:

left hand
1. Forefinger vertical downward—the easiest
2. “ lateral centripetal—next easiest
3. Middle finger vertical downward—more difficult
4. Ring finger “ “ —more difficult
5. Forefinger extensor—most difficult.

way. And as the differences (curve) show better with the negative values as our standard, we have chosen the former method.

INTERFERENCE CURVE.

We now have the question before us of the efficiency curve during interference. We can hardly expect the subjects to do as well in the last revolution as in the first revolution. This we know: there will be a decline in the achievement, but what course will that process take? Will it follow the *treppe* effect of the simplest muscular fatigue? Does it exhibit the drop in the form of a straight line, or does it reveal the influence of the *Antrieb. Anregung, Gewoehnung,* and other such Kraepelinian factors?

On this point we cannot look for any clear-cut results in our investigation for several reasons. In the first place, the different series, as will be seen presently, offer too much variation, as regards this particular matter, for a decisive reply. Then there is also the special difficulty of applying explanations that can be employed with such great latitude and indefiniteness. This is true not only of KRAEPELIN's proposed factors to account for the fluctuations in the course of fatigue, but of all others as well; and THORNDIKE, in his ruthless criticism of KRAEPELIN's findings has scarcely succeeded in fortifying his own position. We don't know any more about the "satisfyingness" and "annoyingness" of a given task than we do about the warming-up process or initial and end-spurts, perhaps even less, for the latter are comparatively simple processes, while "satisfyingness" comprises a number of contributory factors.[83]

The charge of *ex post facto* explanation which THORNDIKE lays at the door of KRAEPELIN's laboratory holds equally well of his own view, since so far, we have not been able to learn the *modus operandi* of the different factors invoked, and consequently we are unable to tell whether the one factor was operative or another, at a given point. In fact, any or all of the enumerated factors might have been responsible for a dent in the curve.

The interference curve, because of the four different components it embraces, is presented here in tabular form for the sake of convenience.

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[83] E. L. Thorndike: Educational Psychology, vol. III, p. 78.

TABLE XI.

Series I.

		Vertical	Lateral	Combined
Revolution	1.	$-97\frac{90}{2}+14\frac{45}{2}$	$-176\frac{147}{2}+5\frac{26}{2}$	$-273\frac{137}{2}+19\frac{71}{2}$
"	2.	$-133\frac{101}{2}+16\frac{51}{2}$	$-210\frac{158}{2}+18\frac{27}{2}$	$-343\frac{258}{2}+34\frac{78}{2}$
"	3.	$-140\frac{113}{2}+12\frac{49}{2}$	$-247\frac{192}{2}+13\frac{30}{2}$	$-387\frac{305}{2}+25\frac{79}{2}$
"	4.	$-163\frac{101}{2}+24\frac{55}{2}$	$-278\frac{165}{2}+14\frac{32}{2}$	$-441\frac{266}{2}+38\frac{87}{2}$
"	5.	$-184\frac{136}{2}+18\frac{72}{2}$	$-276\frac{213}{2}+14\frac{26}{2}$	$-460\frac{349}{2}+32\frac{98}{2}$
"	6.	$-194\frac{133}{2}+14\frac{37}{2}$	$-279\frac{196}{2}+6\frac{40}{2}$	$-473\frac{329}{2}+20\frac{77}{2}$

EXPLANATIONS.

The minus sign signifies omissions, the plus sign, additions. The whole numbers stand for double reactions; the halves indicate single reactions.

Each revolution represents 33 secs.

The omissions and additions in each revolution are out of a total number of 2425 double reactions per revolution for the vertical movement and 2512 double reactions per revolution in the lateral movement.

In the above table we find a pretty regular drop, more plainly seen in the case of the easier movement. There seems to be no room in this series for the *Antrieb, Anregung,* or any of the other agencies believed to operate in continued work.

In the next series, however, we get quite a meandering of the line, and it might be possible to regard the fluctuations as evidence of change of attitude on the part of a number of the subjects. Let us see how this series compares with the last.

The sudden drop in the efficiency curve (next table) between the first revolution and the second, as well as the rise between the fourth and fifth, and also the fact that there is no further drop in the sixth revolution, would tend to confirm the findings of KRAEPELIN and to argue for the identity of the interference curve and the fatigue curve, which would only mean that both processes are governed by common factors.

TABLE XII.

Series II.

		Forefinger	Middle finger	Combined
Revolution	1.	$-337\frac{194}{2}+62\frac{153}{2}$	$-500\frac{278}{2}+29\frac{121}{2}$	$-837\frac{472}{2}+91\frac{274}{2}$
"	2.	$-464\frac{180}{2}+66\frac{136}{2}$	$-715\frac{286}{2}+31\frac{104}{2}$	$-1179\frac{466}{2}+97\frac{240}{2}$
"	3.	$-458\frac{207}{2}+68\frac{138}{2}$	$-837\frac{259}{2}+32\frac{98}{2}$	$-1295\frac{466}{2}+100\frac{236}{2}$
"	4.	$-555\frac{187}{2}+68\frac{138}{2}$	$-918\frac{294}{2}+36\frac{110}{2}$	$-1473\frac{481}{2}+104\frac{248}{2}$
"	5.	$-564\frac{196}{2}+92\frac{183}{2}$	$-888\frac{291}{2}+43\frac{117}{2}$	$-1452\frac{487}{2}+135\frac{300}{2}$
"	6.	$-558\frac{209}{2}+91\frac{173}{2}$	$-867\frac{336}{2}+43\frac{127}{2}$	$-1025\frac{545}{2}+134\frac{300}{2}$
		4150 double reactions per revolution	4696 double reactions per rev.	

Before making, however, any further conjectures in that direction let us glance at the curves of the other two series.

TABLE XIII.

Series III.

		Middle finger	Ring finger	Combined
Revolution	1.	$-179\frac{130}{2}+20\frac{60}{2}$	$-347\frac{283}{2}+14\frac{27}{2}$	$-526\frac{413}{2}+34\frac{87}{2}$
"	2.	$-241\frac{152}{2}+15\frac{52}{2}$	$-457\frac{265}{2}+4\frac{37}{2}$	$-698\frac{417}{2}+19\frac{89}{2}$
"	3.	$-246\frac{162}{2}+20\frac{44}{2}$	$-479\frac{251}{2}+8\frac{42}{2}$	$-725\frac{413}{2}+28\frac{86}{2}$
"	4.	$-299\frac{169}{2}+22\frac{58}{2}$	$-545\frac{259}{2}+14\frac{28}{2}$	$-844\frac{428}{2}+36\frac{86}{2}$
"	5.	$-308\frac{130}{2}+19\frac{70}{2}$	$-556\frac{240}{2}+9\frac{29}{2}$	$-864\frac{370}{2}+28\frac{99}{2}$
"	6.	$-298\frac{140}{2}+33\frac{74}{2}$	$-565\frac{226}{2}+12\frac{32}{2}$	$-863\frac{366}{2}+45\frac{106}{2}$
		2974 double reactions per revolution	3346 double reactions per rev.	

Upon examination it will be noticed that the curve in the third series bears a close resemblance to that of the second series. There will be found here the same wide gap between the first and second revolutions, and the same approximation between the fifth and sixth revolutions, this time in favor of the latter, however.

The same general results are obtained for the fourth series, even in a more pronounced form.

TABLE XIV.

Series IV.

	Flexor forefinger	Extensor f.f.	Combined
Revolution 1.	$-252\frac{182}{2}+8\frac{29}{2}$	$-470\frac{246}{2}+7\frac{37}{2}$	$-722\frac{428}{2}+15\frac{66}{2}$
" 2.	$-315\frac{202}{2}+12\frac{22}{2}$	$-613\frac{237}{2}+14\frac{37}{2}$	$-928\frac{439}{2}+26\frac{59}{2}$
" 3.	$-328\frac{211}{2}+16\frac{33}{2}$	$-656\frac{275}{2}+8\frac{39}{2}$	$-968\frac{486}{2}+24\frac{72}{2}$
" 4.	$-349\frac{206}{2}+18\frac{29}{2}$	$-687\frac{285}{2}+6\frac{29}{2}$	$-1036\frac{491}{2}+24\frac{58}{2}$
" 5.	$-316\frac{209}{2}+15\frac{39}{2}$	$-676\frac{268}{2}+11\frac{24}{2}$	$-992\frac{477}{2}+26\frac{63}{2}$
" 6.	$-328\frac{175}{2}+21\frac{35}{2}$	$-704\frac{268}{2}+2\frac{18}{2}$	$-1032\frac{443}{2}+23\frac{53}{2}$
	2264 double reactions per rev.	2894 double reactions per rev.	

Again we notice the great drop in the second revolution followed by a gradual decline in the second and third revolutions and then a distinct gain in the fifth revolution, with the usual approximation between the fifth and sixth revolutions, which means that the worst work was done not in the last revolution, but in the fourth.

Our tabular curves, we can say then, exhibit the signs of a certain regularity in the course of the work—regularity in the sense of uniformity of phenomena. The first series shows greater regularity in the direction of a straight line and less conformity to the curves of the other series.

It is safe, on the basis of our curves, to declare that there were regular fluctuations in the efficiency of the subjects during the work, but what these fluctuations are due to can at most only be conjectured. So many factors have been proposed that any one of them or several combined might be called in to solve the problem. Such a solution, however, is far from being satisfactory, for the reason that it is too easily manipulated. There is also the probability that under interference conditions, other factors are brought into play which operate only slightly or not at all in work of an ordinary kind. The solution of such problems must of necessity be reserved for future investigations in which the factors supposed to be responsible for drops or gains in efficiency can be tested separately.

SPONTANEOUS REACTION.

The spontaneous tests which were given for the purpose of discovering differences between work under normal conditions and work under pressure brought out the following facts: (1) A good deal of automatism is displayed in the records; (2) the difference between the flexor and the extensor results is more marked for all but one subject here than when working under outside pressure in the form of rapidly alternating stimuli; (3) metabolic fatigue plays a secondary part in the waning of efficiency as disclosed by our interference curves; (4) The subjects fall into two classes according as they can accomplish more (a) while reacting to the rapidly alternating stimuli, or (b) tapping spontaneously with no stimuli in sight.

Before we proceed to give illustrations, let it be repeated here that in these spontaneous tests, the subjects were asked to tap the key in pairs just as they had done all along, and in order to eliminate automatism, they were given the further instruction to try and follow the general arrangement of the stimuli-lists they have been reacting to previously. This was a positive instruction with a negative significance. The purpose in view was not to have them lapse into a rhythmic repetition of the previous reaction, but to alternate at random between the flexor and the extensor movements on the keys.[84] The working period lasted for 3 minutes, and each 30 sec. interval was marked off on the kymograph so as to represent the six revolutions in the ordinary experiments. In this way we could trace the achievement curve of the subjects for every 30 secs.

A transcription of some of the spontaneous records will serve to show what is meant here by automatism. In some cases, the tendency to mechanize is not displayed till the last 30 seconds of the test. The transcriptions of the kymograph records to follow are taken from subjects of different types. In addition, a sample will be shown of the subject least given to automatism, but it must also be stated that this subject, regardless of the fact that no stimuli-list contained groups of 5, 6 or 7 dots (and only one or two contained groups of 4) struck as many as 7 pairs in these tests. The greater scope for variation then may be taken as a partial explanation accounting for the absence of automatism in his case.

Tables XV and XVI, in which the mechanization lapses of the subjects are indicated by the numerals in bold type, are sufficient, we trust, to warrant the conclusion that rhythmic tendencies play a great part in work, and that each subject has his own favorite arrangement. Simple alternation of individual pairs seems to be more universal than other rhythmic arrangements.

As to the degree of physical fatigue that enters into a 3 minute working period, the tables stating the number of reactions for every 30 secs, point to the view that muscular fatigue does not play such a large part as might have been supposed. Of course, it may be urged that in the experiments with exposed stimuli, there is an expenditure of energy in the processes of perception and discrimination. All this is granted, but it will be recalled that in their introspection, some of the subjects spoke of being exhausted in the first minute of the experiment, and actually referred to muscular fatigue in the second revolution.

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[84] The instructions really implied then that (a) there were to be no single reactions, (b) that a group was not to consist of more than three pairs, and (c) the immediately preceding group or individual pair might be repeated, but *only once*. Such were the conditions involved in the ordinary experiments.

TABLE XV.

Transcription of Spontaneous Records.

Subject FG Flexor movement.

1st 30 secs.	22½2½2½222241½1½333
2nd “ “	148342424222
3rd “ “	22422242424242
4th “ “	4522224½22326

Subject FG Extensor movement.

1st 30 secs.	1½22½1½21½1½22412½343
2nd “ “	41½7½23424242
3rd “ “	242422242424
4th “ “	244½241½23½22324

Subject LO Flexor movement.

1st 30 secs.	12241511½2611½2½1111
2nd “ “	2,1½,½3½111141 1½2131121 11½1½
3rd “ “	2114,½4½1211213111113
4th “ “	1,1,1,1,1,4,1,1,4,1,3,1112112½1½13
5th “ “	1,1,5½,1,2,1½,2,1,1,1,1,3,5½1211½,½312
6th “ “	111111½1½24111111411145

Subject LO Extensor movement.

1st 30 secs.	131534½4233½1423½
2nd “ “	112121½121114½41111 21½11
3rd “ “	111½34311½3121211 1½3
4th “ “	11212234 22½1½1111141121
5th “ “	122½1½½31231½2½111
6th “ “	1½11111111½21111111111111½12

Subject SR

It is sufficient to give the values only for the 1st and last 30 sec. periods in this case

1st 30 secs.
flexor { 3 4 2 1 1 1 1 1 4 4 2 2 8 2 1
extensor { 2 7 1 1 1 1 1 1 4 4 2 2 4

6th 30 secs.
flexor { 3 3 2 9 1 1 1 1 1 1 1½ 1½ 1½ 1 1 1 1½ 1 1 1 1 1 1 1½
extensor { 1 3 3 5 1 1 1½ 1 1 1½ 1 1 1 1 1 1 1 1 1 1 1 1 1

TABLE XVI.

Record of RO, showing practically least automatism

1st 30 secs.
flexor { 2 3 1 2 6 3 7 2 3 1 1 3 7 1
extensor { 4 2 1 3 3 2 6 2 1½ 1 2 5 2

2nd 30 secs.
flexor { 1 6 1 1 2 2 2 4 2 6 1 1 3 1 2½ 3 1 1 5
extensor { 3 2 2 3 4 1 2 2 4 1 1 4 1 2½ 1½ 2 1 3 3

3rd 30 secs.
flexor { 4 1 3 1 4 1 3 3 2½ 1½ 4 6 2 2 6
extensor { 1 1 1 1 3 1½ 1½ 2 2½ 1½ 1 6 3 3 4 4

4th 30 secs.
flexor { 6 2 4 2 1 1 3 1½ 2 1 2 2 7 2 1 1 4 2 1½ 1½
extensor { 2 1 2 2½ 1½ 1 1 2½ 2 4 2 1½ 4 3 1 1 2

5th 30 secs.
flexor { 6 2 3½ 2 2 1 7½ 5 5 1 2 2
extensor { 1 3 2 2 4 1 2 4 3 1 1 3

In the efficiency curve of the experiments with exposed stimuli, far greater regularity was exhibited. No subjects did, for instance, as good work in the last revolution as in the first. A drop was noticeable throughout until the fourth revolution. It was only a question of how steep the slope was. The indentations and fluctuations of the curve were few and regular. In the spontaneous reactions, however, we get results like these:

TABLE XVII.

	Subj. FG	Subj. LO	Subj. LZ	Subject SR		Subject VL	
	Extensor	Flexor	Extensor	Flexor	Extensor	Flex.	Ext.
1st 30 secs.	$31\frac{6}{2}$	$33\frac{3}{2}$	$27\frac{12}{2}$	37	31	$43\frac{1}{2}$	$35\frac{3}{2}$
2nd " "	$34\frac{2}{2}$	$30\frac{6}{2}$	$14\frac{25}{2}$	$37\frac{1}{2}$	$34\frac{1}{2}$	$60\frac{9}{2}$	$27\frac{2}{2}$
3rd " "	34	$30\frac{2}{2}$	$27\frac{19}{2}$	26	38	$49\frac{6}{2}$	$25\frac{4}{2}$
4th " "	$35\frac{3}{2}$	$33\frac{2}{2}$	$30\frac{11}{2}$	29	34	$50\frac{7}{2}$	$30\frac{8}{2}$
5th " "	—	$36\frac{5}{2}$	$31\frac{9}{2}$	29	$34\frac{1}{2}$	$56\frac{9}{2}$	$28\frac{8}{2}$
6th " "	—	$42\frac{2}{2}$	$29\frac{8}{2}$	$38\frac{6}{2}$	$32\frac{2}{2}$	$43\frac{6}{2}$	$32\frac{8}{2}$

What this marked difference between the interference curve and the working curve for the same period of time is due to we are not in a position to say. The deviation, however, clearly suggests that different elements are involved in the two processes. The question that presents itself is not only what part fatigue plays in our interference conditions, but the converse, viz., how much of what generally goes under the name of fatigue is directly due to interference? Had we a definite criterion of fatigue under all conditions, our problem should not be a difficult one to solve, but it seems that all we know about the fatigue curve in the more complex cases of work is that it tends generally in a downward direction. With this as our guide, it is plain we cannot measure some other factor which may be either closely or remotely related to fatigue. Nevertheless even with this negative information as a starting-point, an investigation in which both fatigue and interference were studied separately and the one exclusive of the other, would, in the opinion of the writer, go a long way towards answering the double question just put.

In comparing the 'spontaneous' and the 'forced' (rate) records as to achievement, there are certain obstacles that could not be obviated. The most careful calculations cannot give us an idea of what allowance to make for the various elements present in the one and absent in the other. Excluding these considerations, a gross comparison of the two sets of records leads to the conclusion that most of the subjects, and possibly all, made more reactions when the pace was set than when they were left to their own inclination in the 'spontaneous' tests. The subjects about whom there is considerable doubt are LV, SR, and LZ. They accomplished more in the 'spontaneous' work, but it must not be forgotten that the time lost in perception of the stimuli may have been more than sufficient to make up for the difference. All the other subjects did actually more work, encumbered as they were in the ordinary experiments than when allowed their own rate as in the 'spontaneous' tests.[85]

Lastly there is still to demonstrate the fact that in the 'spontaneous' tests, a greater difference was exhibited between the flexor and extensor movements. Subject LO was the only person for whom the reverse was true. If we are allowed for the sake of convenience to talk of the general experiments with the rapidly alternating stimuli as "forced" work in contradistinction to the 'spontaneous' task where the subjects had more liberty, the inference is that if a certain goal is to be attained, a greater amount of effort will be put forth in the more difficult direction than would have been done otherwise. This, again, fits in with and corroborates the previous result, viz., that most subjects showed greater efficiency in the extra-stimulated reactions than in the auto-stimulated ones. In industrial affairs, this fact has been recognized long ago, as proven by the encouragement of piece-work under the contracting system in many plants and factories. Moreover, it is well known that trade unions are openly averse to this system, the question of piece-work pay or a weekly wage figuring greatly in recent strikes, notably in the tailoring trade.

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[85] *Cf.* Dobri AVRAMOFF: Arbeit und Rhythmus, Philosophische Studien, vol. XVIII, 1903, p. 520. "Damit eine grosse Leistung eintritt, muss unbedingt, das *vorgeschr iebene* Tempo *schneller* sein als das selbstgewählte . . . Also p. 521-522 "Laut unseren obigen Ueberlegungen ist also der *Vorgeschriebene Takt unmittelbar nur geeignet, die Quantität der Arbeitsleistung zu erhöhen. Angenehmer,* wirkt aber das Selbstgewählte, als das vorgeschriebene Tempo.

A word or two to explain just how the comparison was instituted between the two sets of movements. In the 'spontaneous' records, the results are naturally in terms of achievement, while in the interference ('forced,' extra-stimulated) experiments, the results have been stated all along in terms of omissions. It was necessary, therefore, first to convert the omission percentages into those of achievement. The single omissions were given half values. Dividing, then, the extensor values by the flexor values, we obtain the ratio between the two movements in either set of experiments as follows:

TABLE XVIII.

Ratio Between Flexor and Extensor Movements.

Subject	Extra-stimulated	Auto-stimulated (spontaneous)
LV	92.11%	60.31%
LZ	79.56%	65.8 %
RO	89.%	78.43%
LL	100.2%	92.04%
FG	95.4%	92.7 %
SR	93.55%	92.2 %
ML	82.76%	81.53%
LO	79.51%	94.4 %
Average	89.01%	82.18%

CHAPTER VII.

INTROSPECTIVE RESULTS.

The main problem before us here is to gain some analysis (1) of the antecedents of the inhibition and (2) of the state of mind during the inhibition. There are, however, many subsidiary points that bear on the work as a whole forming a sort of background or setting for the central issue.

A striking feature that comes to light in the introspection is the feeling of fatigue spoken of by nearly every subject. It is difficult to conceive that we are dealing here with a genuine fatigue factor, for considering that the whole working period lasted only 3 mins. and 18 secs. it is somewhat strange to find one subject (TR in XIII) say, "Fatigue comes in middle of 2nd revolution," i.e., in less than a minute after the work commenced. In spite of the fact that this fatigue is frequently localized, it seems as if it is more of a psychic origin. Many of us have probably experienced a feeling of faintness and fatigue at the very thought of a difficult and responsible task that must be done. Just as frequently do we experience the converse when on finishing some delicate piece of work after hours of great exertion, we feel so fresh and efficient that we could start on another task without any effort. Excessive tension or sudden relaxation are probably the partial causes of such states.

The attitude of the reagent (or agent in actual life) has much to do, it would appear, with the occurrence of the above-mentioned effect. The following bit of introspection from the same subject will make our point clearer.

Subject TR.

Series I, list XII. Rapid first.

"Omitted perhaps half.* Fatigue in arm, and work was increasingly bad. There is a decided tendency to give up and say there is no use. Don't know of any mistakes I made outside of the omissions. Generally behind 4 or 5 and try to catch up, but as soon as the number is greater, I stop and go on to [react to] what I see. The fact that I tap from memory while looking at different dots confuses me somewhat. Not the least difficulty in association. Consciously stop sometimes. Attention on the stimulus not on the movement, not conscious of the movement until I get the pain in the arm from fatigue. Don't like the beginning of the next revolution. [In this list each revolution began with the close dots, thus calling for greater speed] and don't get keyed up for it. Keep a steady pace."

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* This exaggeration which is found in the protocols of most of the subjects is very interesting. As a matter of fact T R omitted less than 1/5 in that particular list.

We see here that the subject thought her efforts were in vain, to begin with, and this thought evidently controlled her whole state of mind during the reaction. In lists X and XI where her "attention was not focussed on the work," she did much better work, and stated so in her introspection.

With the preceding, we might compare the attitude of subject LE who was almost in every respect different from TR, excepting the universal tendencies such as favoring the easier movement, exaggerating the poor quality of the work and the like.

Subject LE.

Series I, list XIII—rapid first.

"Easier than the one before. Don't think I had more than half right.* Very often the finger *would slip from the green* [difficult movement] *movement key to the red* [i.e., the downward reaction] and made a single red. Only muscular inhibitions. React to what is present. Don't try to catch up. . . . In seeing the fast at the beginning of the next revolution, I would do the slow more correctly, *then as the fast of the next revolution came up, I may have dropped the first 3 and started on a 4th.*"

The difference in attitude is even more strikingly brought out in the protocol of

Subject RO.

Series I, list VII—rapid first.

"Liked this series better than the first. It was easier. I knew that I could store up energy for the next revolution. There was catching up in the record because it gradually slowed down. Instead of feeling that I was going from bad to worse, I felt that I was going from bad to better. Attention on the movement. Omitted about 1/10 in the worst and 1/15 in the best revolution.** Omissions not so bad at beginning, then grew worse and towards the end diminished with practice. Maximal fatigue without offsetting by practice about the middle. I *get keyed up at the end of the revolution for the next.* No sensory confusion, but association apparatus grew weak when fatigued. In the last 2 [revolutions] the association apparatus grew better."

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* In reality, it was only about 1/10 that she omitted.

That the attitude[86] of the subject plays some part in the way of either inducing or warping the feeling of fatigue can be seen not only from the fact that sometimes there was more fatigue at the beginning of a record than towards the end, but also from the refreshed feeling with which the subject set to the second record at times. Encountering an obstacle, feeling that one is behind, in a word, the consciousness that one is not equal to the task[87] is liable to bring on not only an unpleasant feeling-tone,

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** His omissions were less than 1/20.

[86] Seeing that the term "attitude" is fraught with so much ambiguity, a word of explanation might be in order. In the first place, then, it should be made clear that the "attitude," as understood here is not necessarily a *permanent* frame of mind taken up by the subject (*Stellungnahme*), nor is it employed in the more technical sense of *Bewusstseinslage*. It is somewhere between the two and represents a possibly changing frame of mind *affected by the situation and conditions faced.* To begin with, a certain attitude is called forth by the personal determinants, but an increasingly difficult situation, let us say, or perhaps the flush of continued success may change this attitude materially, so that it really depends on many factors, and is not entirely subjective, because it is modified and thus partially determined by the run of external conditions.

[87] What is here described as the negative attitude seems to correspond at least in its genesis, to MEUMANN's first type (*rückwirkende Tendenz*) of will-inhibition. Cf. his Vorlesungen, vol. I, pp. 637-638, 2nd ed. Considering, however, that subjects are apt, on occasion, to be possessed with a feeling of confidence as well as with a feeling of failure, though MEUMANN omits to mention this latter phase altogether, it is not easy to see why he should make out of this phenomenon a onesided affair, instead of giving it a generic place with positive and negative values. The concept of attitude is not only preferable for this reason, but also because it is in a way explanatory and takes us a step behind the inhibition especially as "nicht alle Individuen sind für diese Willenshemmungen gleich zugänglich, und wo sie auftreten, wirken sie sehr verschieden, loc. cit. p. 639.

but even the feeling and sensations of fatigue. On any other view, it would be difficult to explain and reconcile certain statements that come up repeatedly in the introspective accounts.[88] Samples of this might be found in the protocols of FG and ML.

Subject FG.

Series 1,—List XII—rapid first.

"Did it better [than the slow-rapid list]. Think this the easier. In second revolution I got mixed up and alternated the wrong way. Looked out for this and got mixed up only once. *Suddenly all my tension relaxes. Feel comfortable* and the speed is slower."

Subject ML.

Series I,—List IX—slow first.

"Thought I only left out about ten dots in the last revolution. Improved towards the end. There was eye strain and *everything seemed blurred in the middle revolution.* There was one place in the middle of each revolution when association would be apt to break down, sometimes only slightly. *Generally speaking the curve of work went up* though irregularly. Fatigue *set in at the very start, but soon this fatigue was underneath.* It was pleasant to finish up the end of one revolution and did pretty well in the last bunch, and then relaxed so much that I had some difficulty in keeping up with the slow ones. Preferred gradual keying up."

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[88] It is gratifying to see that LADD and WOODWORTH (Elements of Physiological Psychology, p. 540) are careful enough to say on this point: "Inasmuch as a short series is relatively free from inner interferences whereas a long series involves many such chances, a short series is apt to be performed with better success than a long series. The appearance then is that fatigue has influenced the longer performance. But *since* even this long performance need be only a few seconds in length, and since recovery from the condition is prompt, such fatigue can scarcely be identified with the progressive and metabolic type." Our results are certainly corroborative of the further statement that "there is apparently a radical difference between metabolic fatigue which really lowers the power of an organ and the inhibitions which result from the action of certain stimuli to the organ. *It is probable that inhibitions or interferences give the key to most appearances of intellectual fatigue."* It is well worth underlining the last sentence considering that the term fatigue had beclouded a number of issues in psychology that are either antecedents of fatigue or else only remotely related to it.

The blurring effect is an important point especially because it is not a rare occurrence. Several subjects have spoken of sensory inhibition, and a few others stated that the stimuli they didn't react to were not perceived in the first place. But why should some dots be perceived distinctly and others not? Here we come upon a matter of great theoretical importance. From many protocols it may be gathered that the distinct perception of the stimuli depends in a large measure on the quality of the immediately preceding reactions. If all goes well, there is no blurring of the stimuli. If the subject, however, had been making mistakes or was lapsing into a state of confusion, the oncoming stimuli would make but a faint impression. It would seem as if in accordance with the Action theory, the motor difficulties produce a blocking of certain higher channels that are involved in apperception and perception. This is by no means an attempt to go into the merits of the various inhibition theories that are in the field at present, but it is well to keep in mind the theoretical bearing of the blurring effect.

METHOD OF REACTION

The introspection reveals that not only are there individual differences in the method of going about the work, but that every subject changes his attitude and method more than once in the course of the reactions. The rate of speed, and the direction of change, i.e., whether the dots are in an ascending order of speed or in a descending order, and sometimes even their number-arrangement—all these factors call forth different determining tendencies. The subject may have been doing one thing for a short period, and a few moments later, he may have adopted a different course entirely. The change was not a chance happening or an arbitrary move. It was brought about by an altered situation.

The most remarkable instance of this transformed attitude was evidenced in going over from the "rapid-slow" to the "slow-rapid" list, or *vice versa,** but reserving the discussion of that point to another section, we have other instances of this fact, bobbing up again and again in the protocols. Here is a good example:

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* Vide sub "Application to Pedagogy."

Subject GD.

Series II—list XV A.—slow first.

"Liked this much better. In the last record [the list was the same, but reversed, so that the rate of speed was in a descending order, i.e., it began with the very close dots] the whole thing seemed to be just as fast as the fast part of this. The first part here seemed slower than the slow in the experiment before. Only twice I found myself waiting for the next dot. *There would be a tendency to alternate during this waiting. When it was going very fast and I was hurried, I would have the tendency to continue the same process. When going very slow I do the dots singly.* When a group is all gone and out of sight I don't try to catch up."

Subject FG.

Series I—list XI—rapid first.

"When I do good work, *it seems to go more slowly.** Made several omissions and one mistake. Had to catch up. Anticipate when seeing the beginning of next revolution and get keyed up. Can count the number of taps by the sound."

Series I—list X—slow first.

"Liked the one before much better. The grouping in this was such that I couldn't keep up with it. It seemed to be a different one [list] from the one before.* Didn't like the side movement. There was inhibition with the green [stimulus for side movement]. Found myself working at wrong dots in this. For a whole string I did the wrong ones and then had to stop and begin afresh. Worst work was in the middle revolution. Then I started improving."

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* The *speed illusion* is one of the most interesting results in our experiments, especially because of its universality; and forms a valuable datum for discussion in dealing with time perception. The explanation of this illusion, which, so far as the writer is aware, has not been hitherto mentioned, seems to lie in the increased tension due to the unrealized impulses.

* Subject F G was the only one who knew that the second list given in the sitting was the reverse of the first. As the large screen in front of the stimulus-cylinder concealed the manipulation of the apparatus, no subject had the opportunity of obtaining this information, except by being told.

Subject RO.

Series II—XXII A.—28″ slow first.

"Attempt every group now but don't attempt to complete it as I used to do before [when rate was not as high]. This fights off the inhibition. The inhibition used to be between intention to do, say, six taps and intention to react on the oncoming stimulus. Here the whole emphasis is on the advance work. My setting is for the new color always."

Series II—XVIII A.—28″ slow first.

"As soon as I felt the lack of control, there was a tendency to relax. As soon as memory images faded out, I let the whole thing slide until I could get another grip."

Subject SR.

Series II—XVIII A.—slow first.

"Contention of impulses in the form of images [did not state what kind] and conscious of both impulses and of the fact that there is a contention. What settles the struggle is complete banishment of both impulses from consciousness. This is voluntary. Yield to the new impulses coming."

Owing to the play of several different tendencies during the sitting, the subjects' statements appear at times contradictory, but it has already been suggested that the methods adopted vary with the course of the work. Subject GD in mentioning the two conflicting tendencies that he experienced made it plain that when he is hurried, he is inclined to continue in the same process instead of alternating in accordance with the stimuli, while in waiting for a dot to appear he has a tendency to alternate. Subjects FG and SR are not as definite. The former tells us that there was a tendency to alternate (with XIV rapid first, which is the easier list for him) and after the next record (XV, slow first) says, "Tendency to continue in the same process, which I had to control"; while the latter (IV 24″) makes it known that there was a "slight tendency to alternate" and almost in the same breath adds "also a tendency to keep on striking the same key."

If the alternation tendency is at work during a moment of waiting it might well be due to anticipation. Another possibility suggests itself quite plausibly. The subject may have experienced the alternation tendency while performing the more difficult movement, whereas the continuation tendency may have forced itself upon him while making the easier reaction. In general the latter tendency was more in evidence, and a distinct effort had to be made to control it.

THE LESSENING OF THE TASK.

In agreement with what has been said before on the *course of least exertion,* the introspective protocols disclose numerous ways of making compromises between the task and the response. It has already been stated that various methods are adopted to suit various moments of the changing situation. The shunting is systematic. The subject has to omit, but implicitly his task calls for an effort to react to every stimulus. It is clear that he cannot proceed and carry out the burdensome instruction in all that it implies. The only course open then is to make allowance in certain cases or to exaggerate one element of the task at the expense of another (compensation). What happens is this: The specific determining tendencies, which vary according to the personal determinants, come into play to counteract the primary or dominant determining tendency. If the latter tendency were to prevail without repression, the subject would be going along at a comfortable pace; but he feels a certain responsibility and this determines him, let us say, to keep on tapping. He does it, however, aimlessly without reference to the stimuli. This is one way of discharging his duty. Now there are many other ways that will be gone into more fully in the chapter on individual differences. Anticipation seems to be resorted to quite frequently, but anticipation of a particular sort. The subject, viz., makes a deposit of a single or double reaction during a period of waiting, and counts it afterwards as belonging to the oncoming group (Subject R U especially is given to this. In Series III (XXI B. 28″ slow first), he says,

"Tendency to continue red, and then count it as the first of a group that hadn't come up yet, i.e., anticipated."

This easing up in attitude is more articulate with other subjects, notably TR, SR and LV. The latter tells us

"I don't appear to see all, but only as much as I can do. Voluntarily omit those that are too much. . . . 'That's superfluous,' 'Two is enough from those there' seem to suggest themselves on the motor side, so my apperception is reduced."

Series III—XVII B.—slow first.

Or again,

"Had a feeling of cutting part off and throwing it away. There was hardly any conflict of impulses. The frame of mind is 'Get what you can and leave the others.'"

Series II—XXIII A.—rapid first.

Similarly subject SR had a tendency "to stick out certain groups only" and take a lax attitude. Said

"'What's the use of trying to catch up.' Apperception weaker for the dots I did not pick out and stronger for those I did."

Several subjects had a tendency to rest satisfied with making a single reaction instead of a double reaction. That was especially the case with the more difficult movement, as may be seen from the tables in a previous chapter. Subject ML states

"would stop short the impulse to react on green [upward movement] every time I'd see a red [downward movement] coming up" (Series IV, xviii c, slow first).

There were also such occasional lapses as these: striking a key with two fingers, striking the two keys with the easier finger, using the knuckle instead of the finger tip, stopping prematurely at the end of a revolution. These lapses are recorded of subjects SR, ML, RO, and FG.

Another subterfuge seemed to be the omission of isolated stimuli. It was the group of two or three that received most attention, except by three subjects. (Of these two regarded the single dot or cross as a group, i.e., to them it was the alternation in color that formed the group.) The reason for emphasizing the larger groups is obvious. There are really two causes for that tendency. In the first place, the larger group is, as far as most of the subjects are concerned, apperceived with greater vividness. The large group makes more of an impression. Secondly, there is greater economy of effort in reacting to three stimuli of the same kind than in alternating from one key to the other. In repeating the same reaction, instead of changing the movements, there is also some time saved.

INHIBITION

We now come to a central point, viz., that of inhibition. To begin with, we must realize that inhibition is but a name for a number of phenomena that have at their root a similar process. In all sorts of inhibition we find one salient feature that really determines their coming under this category, and that is the *checking process.* That is true both of physiological and mental or psychological inhibition. With the former we are at present not concerned. The latter, however, does need some further analysis and classification. In speaking of psychological inhibition one is apt to confuse the cause and the effect, the state of inhibition and its antecedents or else the state proper and the further results. In a sense, every state of consciousness is an inhibition inasmuch as it holds other states out of consciousness. A moment of concentration is an inhibitory state on that score. It is clear, however, that such a broad view would not be of much use, and for technical purposes, it would be but a mere quibble. We must distinguish between the feeling of tension that leads to inhibition and the mental content that represents the latter state. In the same way it is necessary to mark off inhibition from reversals, though lapsing into wrong movements is often the effect of inhibition.

In our experiments, the subjects distinguished three kinds of inhibition. The first was spoken of as sensory and was described as a blurring effect of the stimuli. There seemed to be also a couple of variations in this type, (1) in distinct perception of the stimuli; (2) after-images or "overlapping of visual content" as subject LV expressed his experience on several occasions. In his case, the after-images were of the stimuli representing the more difficult movement.

The second type of inhibition was sometimes called "muscular," sometimes "motor"; and by that the subjects seemed to wish to convey the idea that this inhibition had to do with the realization of the impulse. They associated it with the muscle because they felt it checked them when they were nearer their goal. This type did not appear to be so serious as what they called the "Associative" or "Central"[89] inhibition. It was really the last type that caused most of the mischief, the disturbance taking deeper root and lasting for a greater period of time than with the other two kinds. The associative inhibition frequently brings on the sensory kind, while the associative kind may be the result of the purely motor type, but sensory inhibition never appears first, i.e., there is no blurring effect until the difficulties begin to accumulate. It is probably then, too, that the ignoring of parts of the stimuli-series begins.

THE APPERCEPTION OF GROUPS.

The grouping of the dots seems to be an adaptive device making for greater speed. The higher the rate of speed, the greater is the tendency to regard two or three stimuli of the same kind as a single unit. This is apparent not only from the fact that the slow reagents are apt to show this tendency more than the quick reagents, but also from the two different methods of attack frequently employed by the same subject.

In the section on Reaction Method, we have already found that subject GD would do the dots singly at the slow rate. Other subjects seem to have adopted the same method.

"At the lower speed, I take the dots individually. At the high speed only I group the dots. The grouping is a device to keep up" (LO in XXI A).

Subject LZ, who was the slowest reagent of all, had no opportunity, at any time, to react upon each dot individually. He therefore takes them

"In groups, and at the high speed groups the groups, so that several groups make one group" (XX A).

This tendency may be compared with the apperceptive tendency in reading: Reading at leisure is, in the writer's experience, done mostly in phrases and sometimes even in single words. Very often this is a hindrance in following the continuity of the sentence or paragraph. In spending too much time on the single words we lose the relation or drift of the whole. Many of us get more out of our reading when we do it while in a hurry,[90] perhaps when we are anxious to finish the chapter before the library closes, or when, in the margin of consciousness we feel the immediate pressure of other and more important work. It is then that we take in at a glance whole clauses and sometimes even sentences,[91] by falling into a certain galloping tempo that accents the important and skips the unimportant parts of the sentence, or in the language of JAMES

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[89] These terms were used by the subjects only as convenient expressions and by no means as theoretical suggestions. After the three kinds of inhibitory experiences had been distinguished, it was agreed between subjects and experimenter to understand by such and such a term a particular experience. The subjects employed their own terms; hence the synonyms we find above.

"We give attention only to substantive starting points, turning points and conclusions here and there."[92]

The significance of a group of dots cannot, of course, possess the same significance as a phrase or a clause, yet subject LO who takes

"The dots in groups, especially when they are going fast" gets them "as letters of a telegraph message."

The meaning of the stimuli is constituted by their number, color and shape and possibly also their sequence. The larger the group, the more meaning it has. Also the stimulus of the color and shape recognized as requiring the easier movement is more meaningful than its opposite.

The connection betweeen the apperceptive tendency and the course of least exertion will be brought out in greater relief when we come to discuss the difference between sensory inhibition of the RANSCHBURG type and motor inhibition.

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[90] Cf. TITCHENER: Experimental Psychology of the Thought Processes p. 204; "It is surprising how accurate an impression may be gained by hurried selective reading, 'skimming,' if only one has had sufficient practice."

[91] This of course is outside the question of fixation pauses and eye movements.

[92] James: Principles of Psychology, vol. 1, p. 265. So far writers on the psychology of reading have taken up differences in individual types or differences in material as affecting the rate of reading. From observation, however, we know for certain that the rate varies not only with the individual and with the material, but with the purpose in reading, as Titchener points out in his own case (loc. cit. p. 203); and we might add: with the attitude of and conditions imposed upon the reader. Here, indeed, lies a problem in reading for future investigations.

In order to get at the inhibitory state of mind more closely, it is necessary to start with the antecedents. Generally speaking, inhibition is first caused by a conflict between the impulse to react on a previous stimulus and that of responding to one that has just come into sight, the resulting inhibition may be slight and affect only two or three stimuli. It may consist in the inability of stopping one impulse in time to start for another response. But it may also go deeper than that and throw the subject into a daze. *The degree of inhibition may be measured by the degree of definiteness the subject has of the instructions. That is clear from the accounts to follow.* Inhibition, also has more chances of coming on, the more intent the subject is on his work. Subject F G generally had his attention off his work. The instructions were held in marginal consciousness and he often lapsed into reversals, striking the wrong keys, but as already remarked, that could not be called inhibition. It was only when he caught himself reacting wrongly that he was inhibited and had to stop in order to start anew. The wavering or shifting of attention seems to be the sole cause of reversals, and the reversals eventually give rise to inhibition, i.e., as soon as the subject becomes aware of his mistake.

The most characteristic thing about inhibition is the feeling of helplessness in various degrees. Here is how subject L V describes the rise of his inhibitions:

(Series III—XX B.—rapid first.)

"Hand and eye seem to be entirely disconnected when during slow part of Iist I made needless mistakes. Feeling of astonishment that I should do so poorly at slow rate. First revolution was about 90% right. Second made me shift and put me all out. *I knew I was making reversals and could do nothing.* Internal speech "no" and feeling of ostracism, of self-depreciation I was in the state that I couldn't believe I had done it. . . . There was tension and inner exhortation to do better and feeling as if I were forming a new habit."

In the second record he says

"Consciousness of omissions great. In second revolution there was a reverberation of the omission consciousness, which was turned into reversal. Felt I had omitted and then turned back to make up, with the result of making a reversal. Looked deliberately at red and tapped green [struck the key corresponding to the green dot]. Disparateness of eye and hand. Hand seems to be refractory to decision." In another variation (series IV, XX C, rapid first) it is stated that "sometimes my fingers would stick in the middle of a series of dots, and then I set out to finish it, but different groups came up and then I was helpless; couldn't change right off."

With subject L Z, it was a case of knowing "I have to move a finger, but not exactly the associative arrangement." (Series IV, 1 XVIII C., slow first). Subject R U

"Had a number of omissions, and times when I felt helpless from lack of gathering myself together. That was, however more at the end when I was more fatigued. Then it was just as a red group and a green group inhibited each other." (Series III, XVIII B., slow first.)

By way of parenthesis, and in order to bring into relief the non-inhibitory attitude, let us quote what the same subject reports on the second record that morning, i.e., when the same list was reversed, requiring the most rapid work first. We should expect to find the subject here under the effect of fatigue just as he reported it a few minutes before but *mirabile dictu* he found it "very much easier," in fact, "twice as good" [his objective results bear this out. In the first, there were 32 double omissions and 7 single omissions for the easier movement, i.e., the middle finger, and 48 double omissions and 6 single omissions for the more difficult movement, executed with the ring finger, while in the second record there were 16 double omissions for the one and 29 double and 2 single omissions for the other.]

"Did first revolution perfectly. Had a number of omissions, but no reversals. Easier to start with a color,* I last hit [reacted to] and this is usually red. Tendency to continue a red or a green according as I tapped before. While *I was waiting during a break, my fingers would react automatically to a dot that*

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* It will be noticed that most of the subjects refer to their movements always in terms of the stimulus, probably because the movements were varied while the stimuli remained the same throughout all the experiments both as to form and color.

had passed without real apperception. Notice that I reacted only after finger was down."

The weakening of the determining tendency during inhibition is attributed sometimes to faint apperception, but faint apperception in itself is already a symptom of inhibition and not a cause. The cause lies in a lack of coordination between two impulses where the immediate one cannot find a proper outlet because a determining tendency presiding over another impulse had inserted itself and had set off a more spontaneous impulse.* Meanwhile the apperceptive impulse, i.e., the impulse to react on the very stimulus that is perceived at that moment, and which, under ordinary circumstances, would be immediately executed, is blocked. It is this incident that heightens the state of inhibition. The confusion arising from this state may immediately lead to a break, with the subject doing nothing and his mind in a daze, or else the vague and general determining tendency may be present to react somehow. In this state the subjects react at random, the stimuli having little or no meaning for them. In the former event, the break is much longer, but in both cases, a distinct effort must be made anew, as the determining tendencies reinstate themselves, and only then is the coordination between perception of dots, association of movements and motor ability formed again.

To illustrate from the protocols some of the different stages of inhibition together with their antecedents: Subject R O says

"Felt an impulse to react and there was no outlet. There was a perception of red and green, but no apperception. Then my own muscular inability saved me, i.e., I took only a certain number of the greens. All the difficulty came with the greens" (Series IV, l. XX C, rapid first).

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* Cf. e.g., "I hit a color I didn't mean to hit. Internal speech [with the first] and in spite I hit the other." (RU in XXII C, slow first 28") "Felt a clashing of impulses, almost a muscular feeling of pull to keep on striking the green that I had been striking." (SR in XXI C Aux) "Felt an Impulse of tumbling over. Stimulus was green, and had the impulse to strike red." (LE in XXI C Aux) "When I hit a wrong key, I instantly see that I am wrong, simultaneously with my finger on it, but I can't help it. Once I found myself going wrong, but was helpless and that made me omit the next one" (RC in IV, 24").

Subject L E was

"Worn out half way. Had random tapping. Stimulus not apperceived very well. That's the reason for the random tapping. Apperception was only of form not of color . . . one associative breakdown, and felt that it wasn't due to fatigue. I saw it was green and saw the red, but my muscles didn't work correspondingly, but reversed." (Series IV, 1 XXII, C, rapid first) "When I omit, I see the stimulus, but the impulse is not there, I don't associate the dot with the movement. There is a stupor." (Series II, 1. XVIII A, slow first.)

Subject L L

"Suddenly I see I'm wrong. If there are two or three red dots to tap and can't get them tapped before they disappear, I find myself tapping with forefinger [easier movement] even when a green dot comes. I can't stop the impulse, once it's given, and if I do succeed in doing it, the result is that I have a motor inhibition and can't do anything. . . . After the motor break there is a period when I can't associate the dots with the movement" (Series II, xxi A, slow first). "Realized what I ought to be doing, but would go wrong just the same. It comes on in the high speed" (Series II, 1. xx, rapid first). "When I can't keep up, there seem to be two difficulties. The one is to alternate the impulse, the other is to keep the fingers going fast enough." (Series II, xix A, rapid first).

Subject L O

"Confusion brought about because I start to execute a movement, say with the forefinger, then green dots come up, and I either go wrong tapping out the red [with the forefinger] before [I change], or else am altogether inhibited and don't tap at all." (Series II, xx A, rapid first).

Subject M L

"With inhibition, I had a blank, and feeling of futility marked by organic sensations and strain in fingers and discomfort in hand. Many times I didn't apperceive the significance of the different dots. The association of the movement and the dots was lacking." (Series II, 1. xviii, slow first) "Inhibition would follow the conflict between finger work and apperceived dots. Prepared *for a certain kind of motor* discharge, and this worked itself out, even though I ought to change." (Series II, 1. xix, rapid first.)

Subject R O

"Inhibition to-day was on the sensory side. The fast revolving dots were not apperceived. Caught up from memory part, and part I let go. What I caught up, I reacted to without inhibition, and what was seen during the reaction, did not affect me any more than it was blank paper." (Series II, 1. xx, rapid first.)

Subject S R

"Inhibition caused by the tendency to alternate from one color to the other. Now before I strike up the whole group, another group of the same color is seen, and then there is a real conflict between impulse to react to present stimulus and that to react from memory. This causes an inhibition, a sort of neutralizing effect of the two impulses. Then consciousness of confusion; then comes the consciousness that I ought to be striking, and that memory brings on the unpleasant feeling-tone. During the state of confusion, I don't perceive the dots running by at all. (Series II, 1. xxiii, rapid first.)

Subject V L

"Not able to stop an impulse when other dots are coming in. You know exactly what you ought to do, but can't help it. Feel helpless. Feel as if consciousness had taken in only a fraction of the whole. Most noticeable element in the bodily concomitant of the inhibition is a tetanus. You feel as if you had worked harder than necessary. Hands rigid after inhibition. The *physical* concomitant is crampedness and warmth in hand. The *conscious* side consists of overlapping fields of consciousness as if the 6 times tapping overlaps with 4 and 2 other coming up. It's a feeling of nothing rather than of something. It seems as if the conceptual or perceptual goes off into a physical recognition of failure. It's a *finger* feeling of failure. (Series II, 1. xxii, A, slow first).

In the accounts of subjects L O, R U, and R O we find a description of the more advanced stages of inhibition. The former "felt paralyzed just as if I wanted to wake in my sleep. Upward motion very fatiguing. Had a feeling of powerlessness. Was almost giving it up." (Series IV, 1. xxc, rapid first).
In the second record he

"was dazed and simply alternated at random."

In another record he thought

"it was all random tapping. 3 or 4 times I thought I'd give it all up. Complete inability to follow the stimulus. Plenty of muscular inhibition. Also associative. The whole thing was too fast. Was so confused that I hadn't looked at the dots at all" (Series IV, 1. xviii c, slow first).

And again

"Very distressing experience. Not quite as fatiguing as before. General confusion all around. It isn't confusion in intelligence. It's confusion in volition" (Series III, xv B, slow first).

Subject R O gives a more definite account of the different stages of inhibition that he experienced. Once (Series IV, 1. xx c, rapid first) he reports.

"One blank space owing to muscular fatigue. Inability to react for one group lowered my tonicity. The whole motor tonus was so low that I couldn't react, although the association was there, but less vivid."

Further (Series IV, 1. xxi c, slow first

"Instructions less definite in my mind. Instructions took on the form of 'Move' rather than 'move in a certain way.' Everything obscure, then. . . . Less effort to apperceive distinctly."

Early in the year this subject had marked off three stages of inhibitions where the first began with a "tendency to alternate with increasing speed"; the second stage, "when I did not complete the movement"; and in third stage "I simply did nothing, i.e., I wasn't tapping. That happened only once" (Series I, 1. vi, slow first). The movements in that series were the vertical and the lateral reactions.

We find another version of this stratification. One protocol has the stages classified after this fashion:

(1) "When I try to finish up from memory," (2) "When new dots crowd out the old, and I allow myself to be distracted," (3) "A jumble when there is a batch of green-red and red-green with no definite number in group. Then there is a tendency to alternate [blindly]." (Series II, 1. xvi A, rapid first, 28.")
From the point of view of control, the stages are given as

(1) "perfect control," (2) "when reacting from memory crowds out the new ones [stimuli]," (3) "when the new stimuli crowd out the old stimuli," (4) "'complete confusion." (Series II, xvii A, slow first).

The week after, he states:

> "Didn't feel the four stages as last time. As soon as I felt the lack of control, there was a tendency to relax. As soon as memory images faded out, I let the whole thing slide until I could get another grip. As for inhibition itself, there was a decided sensory inhibition when I was trying to catch up from memory. Tendency to continue the same [scheme of] movements when I lost the sensory cue and was tapping at random." (Series II, xviii A, slow first).

Of a more serious kind is the point

> "of inanition when I saw the thing going by and couldn't catch up. It was no conflict of the one inhibiting the other, but the whole impression was inhibitory, where I couldn't respond at all."

With the increasing difficulty of the variations, the latter type of inhibition occurred more frequently, while the milder form came out in several new ways. Towards the end of the year, with the most difficult movements of all the series (upward and downward reactions), he reported

> "A less advanced stage of inhibition centered round the red (downward movement). Red so easy that I let it take care of itself, and attention was centered on the green (upward or extensor movement), so that whenever in doubt, I got to the upper and shunted off the lower" [confirmed by the objective results].

The more deep-seated kind consisted of a

> "type of general inhibition when I even lost the determining tendency. Saw the thing going round, and the only mental counterpart was the unpleasant feeling that I should have been reacting."

A. RETROACTIVE INHIBITION OF DETERMINING TENDENCIES

On examining the foregoing and other accounts, there can be no doubt that the principle or law of retroactive inhibition* is operative in the interference of will-impulses just as it is a factor in the interference of associative and reproductive tendencies. The application is somewhat different, however, in our experiments. *It is the most specific determining tendency that is the first to wane in inhibition.* Speaking more concretely, the course of inhibition may be traced as follows: instead of executing a particular sort of movement at the moment a particular stimulus is perceived, which would be the tendency operating if everything went without a hitch, the subject is pulled in two different directions with the result that (1) the most specific determining tendency, just because it depends entirely on the momentary coordination between eye and finger, loses its hold on him. What happens next? The subject has not stopped reacting. The *Aufgabe* is still before him, and that too in a specific form. He may omit a movement here and there. His reactions may be retarded, and he may be occupied partly in catching up with a group that had just passed by; (2) nevertheless he still associates the red stimulus with one type of movement and the green with another, and proceeds, amidst occasional omissions, to execute these movements. In this stage, there is no synchronous coordination between stimulus and reaction. The muscles cannot obey the impulse quickly enough, and as other impulses keep rushing on, some of the movements naturally remain unexecuted. Hence the subjects refer to this sort of inhibition as "muscular" or "motor."

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* On first thought the term *retrograde inhibition* might appear more appropriate in this connection than the designation *retroactive inhibition*, but on careful analysis it will be seen that, as in the case of memory, the cause of the decline is the *increased burden of the task*. In the memory experiments of Müller and Pilzecker this accumulating impediment was the *nachgeschickte Tätigkeit;* in our problem it is the *increased speed*, the *sustained effort* and *concentrated attention* taxing the reactive functions of the subject as the work during the sitting progresses.

The next step is somewhat of a digression. At least it forms a dividing line between the foregoing stage of inhibition and the following stages. When the subject reacts with one sort of movement to a given stimulus and with another kind of movement in response to a different stimulus, but has at the outset lost the proper association, he is still performing his task, though the details of the instructions are not clearly in mind. γ There is still a tendency to correlate a change in color with a change in movement. The correlation extends also to the number of the stimuli. Thus we see a certain amount of association is involved in *reversal,* but it is not an association that requires very much attention. Ordinarily, the subject is not aware of any inhibition during reversal. In fact his mind is scarcely on the work, except in a marginal way. It is only when *he catches himself reversing* that he becomes inhibited. With some subjects reversal is very rare.

We now come to the more advanced types of inhibition. As the difficulties increase, the subject becomes less and less aware of the meaning of the stimuli, but there is still (4) a tendency to react, even if it is "wild tapping" as one subject expressed it. This random reacting shows, at any rate, that the *Aufgabe* is still influencing the subject; and the fact that, though carried on regardless of the stimuli, it includes alternation and is not confined to striking simply one key bears evidence that the determining tendency presiding over the alternation of movement is not in abeyance. Lastly we come to the stage when the subject's mind is cognitively[93] almost a blank. (5) There is no action at all, and whatever mental content is present belongs to the affective sort (perhaps a complex of feeling-tone, *Bewusstseinslagen* and emotion).

If on the basis of this analysis we were required to label the different determining tendencies for convenience sake, we should name (1) the most specific of these—the coordinative determining tendency, then in the order of their disappearance, (2) the apperceptive,[94] (3) the correlative, (4) the perceptive and (5) the executive determining tendency. When all of these are inhibited, the *Aufgabe* may still be said to be present in the negative affective tone which accumulates with the increasing inhibition.

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[93] This word is used here advisedly, for the writer is of the same opinion as Colvin who maintains that the degree of *cognitive clearness* does not go hand in hand with the degree of *affective intensity*. To him they are rather mutually exclusive. At least, the one is in the focus while the other is in the background of consciousness. Too often we are prone to mistake indefiniteness and vagueness for absence. There may or there may not obtain that see-saw relation between the cognitive and the affective in consciousness, but of one thing we are certain, viz., that clearness or definiteness is not our only indication of the presence of mental content. But cf. Colvin's illuminating treatment of the cognitive and affective elements in attention in The Learning Process, pp. 255-259.

[94] There are a number of psychologists who avoid the term apperception because of its speculative coloring, and as they find it evidently difficult to replace it entirely by the word perception, they employ the term "apprehension," which in the opinion of the writer is much less satisfactory than apperception. Let it be stated here that "apperceptive" as used here refers not only to the perception of the stimuli, but to their meaning as calling for a definite response.

B. AFFECTIVE TONE AND ORGANIC CONCOMITANTS OF OF INHIBITION.

The affective complex connected with the inhibition may vary from a feeling (or *Bewusstseinslage*) of resignation to the emotional touch of shame and self-depreciation. It must not be understood that there is a feeling-tone with inhibition only. Throughout the work there are all sorts of affective complexes with most of the subjects, but they become most marked during the inhibitory state, and tend to prolong this state. It is difficult to separate out the various elements of the affective complex which comprises generally organic sensations as well, but the protocols contain a large number of references to "sinking feelings," "'feelings of ostracism, of dissatisfaction, discomfort, of relief, suspense, paralysis, confusion, resignation, distressing experience, shame, anger, impatience, disgust, irritation, and despair," besides those put in the form of a metaphor.

The organic concomitants of inhibition are of greater interest to us, because they help to throw some light on the question as to whether inhibition is a positive or a negative state, i.e., is it marked by certain features of its own, or does it become known by the absence of these features and by a suspension of previously experienced activity. Introspection points to the former hypothesis as the true one, though we must be on our guard against considering all of the affective complexes and organic sensations as counterparts of the inhibitory state. Some of them may be antecedents, others may be the effects of the inhibitory consciousness. To determine the time-relation with anything like precision, it would seem to us, is an impossibility, but since no elements other than these were observed by the subjects, one is justified in tentatively building up the state of inhibition out of these various complexes, some of which have already been cited, and others (organic sensations and complexes) are to follow.

To begin with, strain sensations and tension in fingers seem to be general with the subjects, often developing into fatigue.

"Feel kinaesthetic sensations; line of tension from wrist to forearm and sensations of a similar quality behind the neck and verbal commentary that those sensations were there." (L O in xxiii C. Aux.) "Noticed a great deal of tension. Thing most prominent was effort to make finger move at all" (L L in xix C aux.). "Aware of muscular sensations. Had inner speech" (R U in xix C aux.). "Organic sensations in lower part of abdomen. Impatience and tendency to jump up and hold back the dots" (A B in xxi C.)

"Aware of only organic sensations. Experienced tightness in chest and breathlessness just as when you feel that you are in a tight fix and had to do something you can't do; and something of the same tension in fingers. Peculiar feeling of tension about forehead." (L O in xxi B aux.). "Feeling of tension. Kinaesthesis in general, but more localized in arm and back of neck" (R O in xxi C aux.). "Feeling of tension of upward movement. . . . Attitude becomes more tense, rigidity in back" (M L in xxiii C aux.). "Had attention on finger and kinaesthetic feeling. First apperception, and then dot wouldn't associate with the movement. The only way to do is then to stop. Then fully conscious of movements down the body through the fingers." F G in xviii A).

This leads us to another important point, viz., the diffusion of the impulse and the resulting phenomenon of what we should call

SYNKINESIS.

The term as employed here includes not only actual movements of other parts of the body than those necessarily involved in the performance of a given reaction, but also kinaesthesis in such other organs.

The spread of the motor impulse has been observed by numerous investigators in various connections. *Exner,*[95] as early as 1873, notes the spread and intensification of the motor impulse under excitement, with the result that the reaction-time of the subject is shortened. W. W. Davis[96] has found that activities involving certain muscles are transferred to other muscles, and uses these results, along with those of other investigators, to prove the possibility of transference in training. *Wissler* and *Richardson*[97] give an account of some experiments "with these diffused movements in normal unfatigued activity of the arm muscles" from which they infer that "diffusion takes place in both inward and outward directions"[98] *Féré*[99] has collected a number of facts, both from his own results and those of others, to show that the exercise of a specific set of muscles affects other members of the body as well, and to some of these phenomena that are characterized by great agitation generally, he applies the term *"ivresse motrice."*[100] In LANGFELD's work on finger movements, the spread of the impulse is marked by the tendency to move the neighboring finger when the extensor muscle of the index finger is innervated.[101]

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[95] Exner: Experimentelle Untersuchung der einfachsten Psychischen Prozesse. Archiv f. die gesamte Phys. (Pflueger) vol. VII. '73, p. 619.

[96] W. W. Davis: Researches in Cross-Education. Studies Yale Psychological Laboratory VI, pp. 48 and 49, and VIII, pp. 106 and 107.

It is not necessary to dwell any longer on the literature on this subject. That the motor impulse spreads under certain conditions is an established fact.[102] It has been demonstrated in different phases of muscle-activity, but so far as the writer is aware, it has not been connected directly with inhibition.[103] A faint suggestion in that direction might possibly be had in T. V. MOORE's "Study in Reaction Time and Movement," Psychological Review,

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[97] C. W. Wissler and W. W. Richardson: Diffusion of the Motor Impulse. Psychol. Review, vol. VII, 1900, p. 29.

[98] Loc. cit. p. 35.

[99] Ch. Féré: Travail et Plaisir. Chaps. XXVIII and XXXI.

[100] Loc. cit. Chapter XXVII.

[101] H. S. Langfeld: Facilitation and Inhibition of Motor Impulses, Psych. Review, XXII, 1915, p. 472 and p. 474.

[102] MUENSTERBERG in his discussion of *Mitbewegungen* (Beitraege zur Experimentellen Psychologie, Heft IV, p. 192 ff.) does not question the occurrence of irradiation, but seems rather to accept it as a matter of fact. What he does contend against is the exaggerated doctrine of symmetrical bilaterality as an original and universal tendency.

[103] Cf. also JUDD, MCALLISTER and STEELE (Analysis of Reaction Movements. Psych. Review, Monograph Supplements, vol. VII, 1905-06) who explain preparatory antagonistic reactions, i.e., the tendency on the part of the reagent to press down the key suddenly before releasing it—a phenomenon already reported by W. G. Smith in Mind N. S. XII, 1903,—by attributing it to motor diffusion. (loc. cit. p. 166, 182-183.)

Monograph Supplements, vol. VI, p. 59. "For a slower movement . . . dissipated along the wrong paths."

In presenting the following excerpts from our protocols, we shall have to view the matter from a somewhat different angle. The question before us is whether such synkinesis is an asset or liability to the reagent? Most of the cases that have been cited in the literature tend to prove that synkinesis is facilitatory; and it is conceivable why that should be so in a great many instances. But we must not infer that synkinesis exercises invariably a facilitatory influence over the members or muscles actually involved in the activity. Sometimes the spread of the impulse and the resulting general excitement are symptomatic of the inhibitory state and the tension and strain connected with the work, e.g., when there was

"a great deal of excitement, breathing faster, general tension in left foot and arm [ipsilateral] general tension in right hand and some movement [contralateral]. A lot in feet. Tendency to run wild, go up and down and lose counting. Speed was too strong. Have spoken of having tension in right arm before, but it was more pronounced this time" (L L in xxiii C aux.)

Sometimes a transference of this sort did not go together with great excitement, and probably betrayed a tendency to rest he one hand and try the other for some time, hence there was

"kinaesthesis in forefinger of other hand" when "muscles would go only as fast as the slower rate" (R U in xxiii C).

"Rigidity of forearm, extreme fatigue, and tension in left arm. Found my right arm in sympathetic rigidity and sympathetic tapping. General stiffness all round body." (L V in xviii A).

It is quite different, however, with subject R O who reports a sort of paralysis of will when he couldn't react and

"*Instead of a definite specific movement, there was as a result a diffuse general movement over the body.* Finally I jumped up from the chair."

The diffusion here was undoubtedly due to inhibition, and far from facilitating the proper movements, it all the more interfered with their rapid execution. For it stands to reason that while a certain amount of general excitability may increase the work-power of a particular set of muscles, the general diffusion of a specific impulse over various channels not directly related to the muscles actually engaged must lessen the effectiveness of the latter.

One subject (S R) was observed to mark time with his right foot while striking the keys. This type of synkinesis seems to be a rhythm phenomenon and was performed unconsciously.

CUE OF MOVEMENT.

With regard to the rôle of imagery in the initiation of movement and general guidance during the work, there are good reasons for supposing that nearly all, if not all, subjects resort to images of one sort or another, mainly kinaesthetic, while performing their finger movements.[104] In many instances kinaesthetic images and sensations were all the subjects were aware of at the moment the cylinder stopped revolving, and they were asked, in accordance with previous instructions for *momentary* introspection. In these momentary introspection tests only three subjects omitted to say anything about images, two of them doing the poorest work of all.

Some of the references to imagery recorded in the protocols follow below.

Subject F G

"Inner speech or kinaesthesis meaning 'right' 'left' " (xx A). "Kinaesthetic feeling of red with down [movement]. Fusion of green with kinaesthetic feeling 'up,' meaning 'all right' " (xix C aux.). "Perceiving the green dot and kinaesthetically perceived the movement for it and corresponding with red, and satisfaction with it" (xxi C aux.).) "Kinaesthetically made [initiated?] movement which meant red down" (xxiii C aux.).

Subject L L

"Towards end I had some false anticipations, sometimes I would be right, but many times wrong. I get it from memory. Partly visual and partly kinaesthetic in fingers and organic" (xix

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[104] Cf. H. S. LANGFELD: Voluntary Movement under Positive and Negative Instruction, vol. XX, 1913, p. 473 and also J. C. BARNES: Voluntary Isolation of Control in a Natural Muscle Group. Psych. Review, Monograph Supplements 93, pp. 42-43.

B). "Had kinaesthetic memory of the dots, but not correct all the time. Felt it in my fingers, so that I would not react all the time upon what I saw. This is not mechanical rhythm simply, because I felt what was coming. This stood in good stead when eyes grew fatigued. Had however no idea of numbers in this imagery" (xiv B). "Kinaesthetic imagery here too. . . . This imagery helped me to read the dots better" (xv B). "Tilting of head and vague inner speech goes with different impulses" (xix A).

Subject L O

"Saw red coming and was preparing for red *saying to myself* '2 red' " (xxi C aux.). "Tension in fingers and verbal affair in mind. Some joke in margin. . . . Have *visual-kinaesthetic* images of up and down" (xix C). "Verbally saying to myself what comments I should give when stopped. Internal speech always accompanies my work." (xxi B aux.) "Verbal commentary. Phrases like 'that's rhythmical,' 'that's pretty good' and so on." (xxiii C aux.)

Subject M L

"Feeling of tension of upward movement. Just about to strike for green, i.e., muscular sensation was in forefinger *meaning upward movement.*" (xxiii C aux.) "Tension in fingers and preparedness to go on when I was stopped" (xxi B aux.).

Subject R O

"Clue to the movement is kinaesthetic image of movement" (II, 15"). "With the tapping of the down, there was a coincident getting ready, a premonitory feeling of the next perception. While the green was in the periphery, the getting ready [for it] was in the organic background, but can't localize it" (xxiii C aux.).

Subject R U

"Counted internally 1 — 2 — 3 as you stopped me. . . . Remember the greens and reds in *motor terms of position* and as I tap them I count them. It seems as if I don't memorize the *color,* because I didn't say '3 red, 3 green,' but '3 of this' and '3 of that.' " (xxi B aux.) "Kinaesthetic sensation from the red I was tapping and perception of a green. Internal speech of 'green,' and something like a *kinaesthetic-visual* image of my finger going up, localized in right place. Hadn't yet reacted" xxi C aux.).

Subject V L

"Know that I have tapped correctly by auditory memory. Haste or trepidation will destroy the after-image of the count, and the consciousness or feeling of pressure" (xxiii C). "There were three sets of elements: (a) visual of red and of green, (b) multiplication—auditory imagery, also verbal and kinaesthetic, (c) association of red with forefinger, association of green with middle finger. Now in consciousness any one of these six classes might be prominent."

The reference here is evidently to the foreperiod prior to making the movement.

Subject L Z stated merely that red *meant* to him "down," while green meant "up." He told, however, of having internal speech (saying to myself '2 reds' "), but did not speak of any other imagery.

Recovery.

Imagery is also serviceable in the final readjustment after inhibition.

"To get right again, I must recall the foreperiod again" (F G in xviii A). "When starting anew, inner speech would reinforce coordination" (R U in xvi A). "In the blind tapping there is at least this central: that there is a tendency to break away from it. I recognize that I am wrong. It may be a verbal statement or auditory imagery (L O in xxi A).

Inner speech is sometimes resorted to as a protective measure to ward off an imminent break. Thus:

"I felt that my control was not equal to the task. I saw the dots, but couldn't hit them." Inner speech came in then" (R U in xvii A). "Inner speech . . . most pronounced when the dots are thickest, [i.e.,] where there is greater speed required. Say '3 red, 2 green, 3 red' etc." (LZ in xxi A).

There are other accounts of recovery in which imagery is not explicitely reported, but where the presence of some imaginal content may well be suspected.

"After the motor breakdown," says subject L L, "there is a period when I can't associate the dots with the movement. But gradually the association comes back again." (xxi A).

But how? He says further that there is some

"feeling connected with the building-up—a feeling that it's all right."

But this feeling need not be devoid of organic and kinaesthetic elements in general. There is the same inadequacy in the description of subject L E, who says that after an associative stupor

"I feel the gradual building-up of association" (xviii A). At the same time it may be assumed that the associative recovery and the motor recovery are not simultaneous, that the former is prior to the latter, and that imagery might go with the one and not with the other, or at least that it might be more difficult to detect in the one than in the other.

MOMENTARY INTROSPECTION.

The momentary introspection tests which were adopted as auxiliary means to facilitate analysis revealed some interesting facts. Some of the results have already been cited under separate headings, but it would be tedious to have an exhaustive index of all the details that were observed by the subjects during the working period. Generally the momentary introspection test brought out the mental content of the moment only at which the work was abruptly stopped. In some cases, however, it would seem as if the very abruptness of the stop served to stimulate introspection. The introspective account does not even here necessarily cover the whole working period, but may be confined to a single moment or two. That moment, however, is closely analyzed and is typical of a great many moments of the working period. A few miscellaneous quotations from the protocols will show the value of such a method.

"I had just made a downstroke. I had a general idea of reaction, but not of a specific reaction. Consciousness that I had reacted to a red, and started on some reaction, but it was only after you stopped me that I saw it was green. You stopped me just as I ended the red" (R O in xxi C). "Feeling of tension of upward movement. Whether I tapped or just about to, I don't know. *Impulse* = perception of dots + general feeling of tension. The general feeling of tension has discriminated parts, sometimes meaning red and sometimes green. No instruction before me in words, but a general attitude. In rapid tapping, attitude becomes more tense, rigidity in back. When things go wrong, the attitude is the same, *but in going more wrong there is a tendency to relax and the instruction which is the attitude changes.*" (M L in xxiii C) "'I tapped a green just when I should have tapped a red. I tapped 3 greens and observed red, but then greens came up and was going to tap the red [that just passed], but the greens took up my impulse. A little annoyed" (F G in xxiii C).

The occasional inability to stop immediately after the signal is observed is something that impressed the subjects considerably.

"You got me in down flight, and even after you stopped me, I made a down movement. 'Go ahead' in consciousness" (R O). "Saw red and green after [apparatus] stopped, but couldn't stop immediately. Finished it up" (L E).

Subject L Z said once he stopped immediately when his finger was seen fluctuating for some seconds after the signal was given. At another time, however, he said his finger was already starting to move after he was supposed to have stopped.

It is evident that it takes a distinct effort to stop at a given moment, just as it takes an effort to switch over from one key to the other in accordance with the impulse to do so.

There is a certain amount of inertia to overcome in both cases.

CHAPTER VIII.

INDIVIDUAL DIFFERENCES.

I

That there would be marked individual differences in the mode of reaction to the whole situation can easily be expected from an experiment such as the one under discussion. The movements in the response were simple, and yet, judging from the results it is evident that a number of possibilities are open even in a simple task—simple but difficult, on account of the time consideration. There is scarcely any doubt that this latter element was instrumental in bringing to light many individual differences that would otherwise have remained latent, just as in actual life, it is under conditions of strain that a person's character gets to be known.

GROUP DIFFERENCES OR TYPES.[105]

In general, most of the subjects fall into two distinct groups in respect to several tendencies, and there is reason to believe that these various tendencies are not totally disconnected. An indeterminate or intermediate group is made up of those who do not show any pronounced leanings in their methods or who vacillate between two extremes. The subjects included under this group are few as compared with the others; and as a rule, even the most indeterminate or most inconsistent behavior bears the earmarks of some sort of affiliation with the one group rather than with the other.

1. The most elementary division is of course that of (a) *quick* and (b) *slow* reagents. All of the quick reagents had had some practice with musical instruments or in typewriting, but since one or two among the slow reagents had also had training of this sort, we must conclude that finger practice is not the sole determining factor of the reagent's speed. Most probably other variables entered in as well—these depending on the individuality of the subject. Those of medium speed may be grouped apart.[106]

2. The next most salient divergence, and one less obvious, is that between (a) the confusers and (b) the omitters. The former seem to lay most stress on speed. Their omissions do not extend over large stretches, but represent solitary spots here and there, while the latter, when hard-pressed, stop working for 10, 15 or even 20 seconds. They have this advantage, however, that they very rarely make a reversal and never carry on any random tapping. Confusion for them is immediately followed by a complete break in motor activity. The confusers, on the other hand, do not stop until they regain their full associative clearness, but keep on reacting incorrectly for some time.

It is noteworthy that the *omitting* group is made up of the slowest reagents, while those who do the rapid work are given to confusing. The one who seemed to disregard the stimuli most was the one who did the most rapid work. In many records he actually made more movements than the stimuli called for, but a considerable percentage of these movements were wrong reactions. The evidence, in general, seems to point to a certain correlation between quickness and the tendency to confuse, on the one hand, and between slowness and motor inhibitability, on the other.[107]

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[105] STERN's moderate view and broad definition of "psychological type" would obviate such objections as THORNDIKE's. cf. STERN: Differentielle Psychologie, chap. XII.

[106] Cf. O. OEHRN: Experimentelle Untersuchungen zur Individualpsychologie, Kraepelin's Arbeiten, vol. I, p. 146.

The question naturally arises as to the grounds upon which we judge a subject to be slow or quick. Is it on the basis of the actual number of movements? Then is it not a rather circular procedure to say that the omitters are the slow reagents? For had they chosen to make mistakes rather than to omit when confused, they would likely be classed with the quick reagents.

To be frank, the writer sees no way out of it, as the different tests that were given the subjects do not reveal any clear-cut index of their quickness to react in a given situation. In the 30 second tapping test, some of the slowest subjects manage to make a high mark, while in the "spontaneous record" test, the slowest subject takes the second rank as to the number of reactions performed. All this goes to show that tapping ability is quite a different thing from the ability to react quickly under interference conditions; and when a subject is here spoken of as being slow or quick, the reference is to his *speed under pressure and against time.*

The writer does not wish to convey the perfectly obvious idea that those subjects who are given to omitting will be regarded as slow reagents, but rather that those who are slow to react upon a situation such as we are dealing with are the ones to be affected by interference conditions in such a way as to have long inhibitions during which their activity is completely paralyzed. The two propositions are certainly not identical in significance. The point does not hinge on the *degree of omission* in either of the two groups, but on the fact that we are dealing with two different types of people characterized by *two different tendencies.*

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[107] Several attempts have been made to correlate personality with the speed and energy of one's movements. That of PEREZ is probably the most noteworthy. His belief was that personality depended upon the degree of quickness or slowness combined with the degree of energy an individual is endowed with. (B. Perez: Le Caractère et les Mouvements, Rev. Philos., XXXI, 1891, p. 50.

For a classification of temperaments based on the subject's celerity of movement, cf. also W. W. DAVIS: Researches in Cross Education, Studies Yale Psych. Lab. VIII, pp. 85 ff.

3. (a) *Equalization* and (b) *undulation* form another set of differences, i.e., some subjects show a tendency to attempt every group of stimuli, while the reaction method of others presents crests and nodes. One group will be tapped out completely, while another group is allowed to pass without the least response to it. The subjects who follow the first method tend to equalize the groups. Their efforts are more distributed, while those who are inclined to complete a whole group before they pass on to another, show a tendency to favor the larger groups and omit isolated dots. Here too there are signs of correlation, the omitters corresponding to the undulators; the confusers to the equalizers.

4. As to the manipulation of the groups, it has already been stated earlier that the method varies not only with the subject, but with the situation. The rule is to group the dots, but several subjects, at times, reacted to the dots individually, relapsing to the grouping device whenever they found themselves hard-pressed for time. One subject was inclined to react to the dots individually most of the time, while two others not only grouped the dots, but, at the high speed, grouped the groups.

5. An interesting individual difference was brought out by the way in which preference was shown for either the ascending rate or descending rate of speed. Some—and these were the quick reagents—liked to begin with the most difficult end of the list first so that they could relax afterwards. Others, representing the slow reagents, preferred and did much better when the arrangement of the stimuli called for a gradual speeding-up. That this division is, in the last analysis, not due to actual individual differences, but is dependent on the relative difficulty of the rate, to begin with, will be explained in the section on applications to education and pedagogy.

6. There is still to note that the gradual change of speed does

not affect all subjects in the same way. With the majority there is a tendency to speed up and to slow down *pari passu* with the rate. Subject LV who is the quickest reagent finds it difficult to slow down after starting out at full speed. The slow reagents, on the other hand, hardly ever speed up. Two of them, TR and TT, keep a steady pace or nearly so all through the record, while two others, SR and ZB, actually do less work at the high speed than at the slow rate. This falling off, in their case, is due to the long inhibitions that come over them, during which their activity is brought to a standstill. It may be added too that the quick reagents find it more difficult to stop the momentum of a given impulse than the slow reagents; also that single reactions occur much more frequently in the records of the former, while the latter follow more closely the instruction to react twice for every stimulus.

B. Individual Characteristics.

The differences that have just been discussed are really group differences rather than individual differences, though usually spoken of as such. To be sure, we must not assume that every single subject will display entirely different tendencies. A manifestation of individuality to that extent would be too much to expect at present even from the minutest study of individual differences. For the time being, it is sufficient to classify a body of subjects according to type, with the understanding that within a given group, the subjects will differ amongst themselves *in degree.*

But this in itself already constitutes a basis for further analysis. Moreover, the *particular combination* of tendencies serves to single out the individual from amongst his group; and in this way we can make, at least, a superficial examination of every subject individually. The individual remarks to follow are an epitome of the series of observations recorded by the experimenter as a supplement to the computations and introspective protocols.

REMARKS.

Subject FG

Quick reagent. Uses kinaesthetic imagery almost exclusively. Given to reversals. Takes task most coolly. Reacts with attention in the margin. Least inhibition. Shows greatest tendency towards compensation as well as lapsing into single reactions (instead of double ones). Attempts every group. Preference for easier movement less decided than with other subjects. Shows evidence of rhythm by *recurrence* of same mistakes in succeeding revolutions.

Subject GD

Medium speed. Imagery, kinaesthetic and visual, confuses somewhat, and experiences a great deal of sensory inhibition. Compensation marked. Breaks down at about the same spot in each revolution. Repetition of former errors. Work regular and tendency towards rhythm. Thus if subject once starts on an odd number of reactions, he will keep on tapping an odd number for some time. Lays emphasis on group, but changes his method to suit conditions.

Subject LE

Medium speed. Kinaesthetic Imagery. Given to compensation. Tendency to make up in slow part for loss at high speed. Favors rhythmic movements. Tendency to make an odd number of reactions. Frequently makes superfluous reactions. Numerous reversals and confusion.

Subject LL

Somewhat slow reagent. Mixed type of imagery with voco-motor and organic elements prominent. Synkinesis and compensation much in evidence. Movements irregular. Picks up towards the end of the work. Leaves the last part of the one revolution so that he could start well on the next revolution. Shows signs of "nervousness" and fumbling in his movements. Affective tone pronounced.

Subject LO

Speed medium. Visual and voco-motor imagery and some auditory also. Does uniform work, but affected greatly by inhibition. Blind tapping, yet manages to maintain a certain order (rhythmic?) during such reactions. Slurs the single stimuli for the sake of the groups, yet does not complete the whole group. Noticeable compensation and some transposition.

Subject LV

Quickest reagent as to output of work. Auditory imagery predominant, also voco-motor and kinaesthetic. Gets after-images of green stimuli (=more difficult movement). A great deal of confusion and blind tapping. *Far greater innervation than necessary,* especially at high speed, with the result that there were more superfluous movements than omissions. Emphasizes odd number, tapping three times instead of twice for one stimulus, 5 times for 2 stimuli, and 7 times for 3 stimuli. Work uneven, strokes on kymograph at various distances apart. Repeats former mistakes. Much compensation and synkinesis. Most of confusion occurs with the more difficult. With practice, the innervation becomes less exaggerated and more normal, insuring greater accuracy, but causing more omissions.

Subject LZ

Slowest reagent. Visual type. Some voco-motor imagery, but no kinaesthesis otherwise. Simply omits, but does not confuse. Scarcely any single reactions. Sticks entirely to the instructions asking for a double reaction. Additional taps very few. The group is for him important; hence he favors the larger groups and those he reacts to he completes. Long inhibitions coming on periodically. Compensation, transposition, and other tendencies of a spontaneous or mechanical sort *not found.* Gains a lot by practice.

Subject ML

Most indeterminate subject. Oscillates between quick and slow type. Imagery visual-kinaesthetic with organic elements. Changes his method frequently. At times, is given to making reversals; at times, he simply omits, but does not allow himself to be confused. Consciousness centred around more difficult movement. Compensation tendency slight. Strokes on record point to regular work. Lapses frequently into single reactions and occasionally resorts to blind tapping.

Subject RO

Quick reagent. Kinaesthetic imagery. Energy or innervation increases and decreases gradually with rate of stimuli. Lapses into single reactions when rushed. Tendency to make up in slow period for the loss during high speed. As a rule, attempts every group. Determination and effort shown by motor diffusion throughout body. After very strenuous work shows a sudden breakdown. Then after a period of omission, he begins well afresh. Centres attention around the stimulus corresponding to the more difficult movement. Lets the other take care of itself. Does very regular work. Compensation tendency very slight.

Subject RU

Quick reagent: voco-motor, kinaesthetic, and visual imagery. Combination of automatisms—(a) must struggle against tendency to continue making the same movement. During slow part, spontaneously adds reactions while waiting for next group of stimuli. (b) Breakdowns seem to be periodic—one long one at the middle of the revolution and a shorter one towards the end. (c) Occasional rhythmic stretches, e.g., 2a, 2b, 2a instead of 2a, 1b, 3a. (d) Repeats mistakes of former revolutions, and sometimes seems to mechanize a certain arrangement regardless of the actual stimuli. In xxii B an additional single tap is found at the same place in 4 different revolutions. Compensation tendency slight, but presents a few cases of transposition. Of the quick reagents RU is the one least given to lapsing into single reactions. Confusion comes in with the more difficult movement, only very rarely with the easier one. Tends more than the others to react from memory, i.e., tries to catch up. Does not attempt every group as the other quick reagents, and slurs an individual dot for the sake of completing a group.

Subject SR

Next slowest reagent. Never reports kinaesthesis and is probably of the visual and auditory type. Does not speed up with an increase in the rate, but keeps a steady pace. Very rarely allows himself to get confused, but simply omits at the high speed. Reacts in pairs, as a rule. Compensations few. Reacts in snatches, i.e., completes one group, then misses the next. Has very long inhibitions. Does less work when the stimuli are thickest.

Subject TR

Slow reagent. Visual and voco-motor imagery. Does not report kinaesthesis. Seems influenced by negative attitude or feeling that the task should not have been given because too difficult and exacting. Reacts with a certain regularity and deliberateness. Very few *mistakes* made, but a great many *omissions.* Seldom makes a single reaction. Emphasizes the larger group and slurs the isolated dot. Keeps a steady pace. No compensation. In general the work bears a striking resemblance to that of LZ and SR.

Subject TT

Slow reagent, but on the way towards rapid improvement. Strokes on record show uneven work. Some incoordination apparent. Much compensation and some confusion and blind tapping. Adds in the slow part and magnifies the larger group, but loses a lot at the high speed. (Data insufficient as to other characteristics.)

II. Personal Determinants and Personality.

We have seen that the subjects fall into two types (with an intermediate, in one case an indeterminate, class) and that certain characteristics, at least certain constellations of tendencies, are ascribable to every subject. It now behooves us to inquire into the significance of it all. In what direction are we to look for an explanation of these individual differences that seem to have such a conspicuous place,[108] especially in the department Stern[109] refers to as Psychical Energetic? Most of us would have thought that the adoption of a method for the working out of a problem is inseparably bound up with the mental make-up of the individual subject, that it is not a merely accidental affair. It is disappointing then to read in WASHBURN's thoughtful treatise on movement an utterance which, far from shedding any light on the subject, only serves to befog the issue. In attempting to account for the different stereotyped methods that subjects adopt when given vague and indefinite instructions, she says:

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[108] Psychologische Arbeiten (Kraepelin) generally and particularly Oehrn's Exp. Studien zur Individualpsychologie in vol. I.

[109] W. Stern: Ueber Psychologie der Individuellen Differenzen, p. 117.

> "It seems to me that these self-imposed problems can be explained simply in the following way. A very general problem sets in readiness a number of methods for its solution. One of these methods happens to be the first one adopted, and simply perseverates: since the influence of perseveration involves so much less fatigue than the influence of the activity attitude, it is not interfered with and becomes increasingly strong."[110]

We must all admit it a laudable undertaking to reduce an explanation to the lowest terms, but when these terms read zero for both the numerator and the denominator, we feel that the simplification has been carried a bit too far. To account for individual differences in the performance of a task by saying that they arose accidentally is merely to take refuge in an asylum of ignorance. In former times, it was the *miracle* that was appealed to as an all-embracing explanation. More recently, it would seem that *chance* is occupying this position of a wholesale difficulty-resolver.

In the writer's opinion to dispose of the matter in this way is no more satisfactory than the child's replying "because" to questions it cannot or would not answer. If we examine WASHBURN's tentative explanation, we shall see that it rests on half a dozen hypotheses, one propped up by another.

Suppose, for a moment, we applied the theory in our particular case. Shall we say that some subjects *happened* to lay more stress on completing a group or on making a double reaction or on the fact that they are not to make mistakes, while others just *happened* to emphasize other factors? It is needless here to analyze the concept of chance and to distinguish between the strict meaning of the word and its conversational content, as this has been done so often. Suffice it to say only that the word "happen" as applied to a person's action is different from the connotation it has when employed in connection with the throwing of dice. "Oh, I just happened to be thinking about it, that's all," we dispose of our curious friend's query. Yet any one who has had a smattering of psychology knows that we didn't *just happen* to do it, in the strict sense of the word.

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[110] M. WASHBURN: Movement and Mental Imagery, p. 173.

In the first place we might ask *how it happened* that a given subject should happen to hit on a certain method of doing things and not on another first. But secondly, WASHBURN has still to prove that a method once hit upon will perseverate. Our results certainly do not show it, and what is more, the facts flatly contradict this assumption. We have already seen that (a) methods are changed to suit the circumstances, (b) subject ML frequently vacillates between different methods. In addition, however, the possible correlation of tendencies among the different groups seems to indicate that we are dealing here with a more complex arrangement than might be supposed from WASHBURN's account.

Were it not for the fact that there is a growing tendency in certain quarters[111] to simplify matters by disregarding them or shifting the emphasis on some irrelevant point, it would hardly be worth while to discuss WASHBURN's view at such great length. She herself probably recognizes the innate character of a great many individual differences, at least, but if so, it is all the more astonishing that individual differences of such a marked and significant character as those falling under the class of *energetic* should be treated so unceremoniously. What prevents us, on that score, from maintaining that differences in imagination are due only to fortuitous variation, that we *happened* to hit upon a certain type of imagery in early infancy and—after applying the rest of the hierarchy of hypotheses—here we are, using one type of imagery more than another?[112]

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[111] Aesthetic preferences are sometimes explained after this naïve fashion or by attributing them invariably to childhood experiences. Barring the limited number of cases of dislike to which FREUD's repression theory might apply, this hypothesis seems to be a vagary which brings to light the defensive reaction of the less fortunate people in matters of taste. They might be interpreted as saying "Our aesthetic appreciation, it is true, is not what it ought to be, but then we have met with an accident, and are not to blame for it."

The whole point of view that is attached here betrays a hankering after an obsolescent, if not obsolete, *Weltanschauung,* viz., that of historical materialism, but without its philosophical breadth; for BUCKLE only denied the existence of original traits, but it never occurred to him to explain palpable differences on the basis of fortuitous events. The *tabula rasa* doctrine, in its extreme form, or better still, the *tabula rasa temperament* is at the root of this whole "scientific" method.

If individual differences stood for nothing more than chance happening developed by habit, differential psychology would not have made such phenomenal progress as it did within the last two decades; and it is to be hoped that in the future there will be more and more intercourse between that branch of psychology and physiological psychology, and also biology. For the history of a person's individual tendencies—even as regards interpreting and acting out indefinite instructions or adopting a particular method as distinct from others—begins not only with the protoplasm of a given individual, but farther back.

At the present stage, a task of such proportions, i.e., of tracing the origins of individual differences, would naturally be out of the question. But surely we have a right to postulate that in the individual psychophysical make-up, there is a *something* that determines him to take one course of action rather than another;[113] and inasmuch as this *something* manifests itself in innumerable ways, and varies from individual to individual, we must recognize that we are dealing with individual determining tendencies. Again when we ask ourselves what further significance these individual tendencies have, the reply will be that it is these tendencies that constitute the *personality* of the individual. Hence we might as well substitute the term "personal determinants" for that of individual determining tendencies. It is by a person's acts that we judge his personality, and whether valid or not, we have to accept for practical purposes the trite saying that a "person is what he does."

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[112] It is of course realized that WATSON, and happily not more than one or two others, would have us first prove that there is such a thing as imagery altogether, but until they prove that there is such a thing as sensation, or else adopt an objective terminology like that of NUEL, we are quite safe; and if they some day decide upon the latter course, we are even safer. . . .

[113] *Cf.* JUDD, (Movement and Consciousness, Psych. Review Monograph Supplements, vol. VII, p. 215). "Individual nervous organizations are clearly of importance, as shown by the fact that certain types of reactions are repeated by given individuals."

For a long time character has been associated with volitional acts.* Ethics was largely instrumental in throwing this connection into relief, but scientifically nothing had been done to prove the relation. The first experimental attempt to study personality in the laboratory was made by ACH[114] who evidently thought the will-act peculiarly suitable for bringing to light temperamental differences. Yet the brief space in his book devoted to observations on temperament by no means justifies the pretentious title of the book, even if we include the scattered references in the body of the work to that phase of his subject. The part on temperament is nothing more than a side-issue with him.

All that ACH's experiments really amount to in their relation to temperament is to show how certain phenomena that he had observed in connection with will activity do fit into the old scheme of temperament. He did not start the subject anew, but had the ancient classification to begin with, and he merely grouped his subjects in the one category or the other, on the basis of their determination, motivation and excitability. The only new and important fact that he contributes is the addition of a fifth type of temperament to the traditional set of four, which he calls the *deliberate* (*besonnene*) type. It is marked by a tendency to obviate all the obstacles that interfere with a prompt reaction, and to avoid slips. The affective reaction becomes less intense as the determination towards an accurate and rapid reaction becomes stronger. With these subjects, success was accompanied by the awareness (*Bewusstheit*) of "I am able," while failure brought on a state of self-irony with the awareness "If I only seriously want to." Great associability of ideas is also a mark of this temperament.

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* Cf. Ed. Hirt: Ueber empirisch begründete Bewertung der normalen und pathologischen Handschrift. Archiv für die gesamte Psychologie, vol. XXIII, 1918, p. 358. "An Stelle des allgemeinen Begriffs des Willenstypus wird darum heute die einzelne Willensbewegung zum individualpsychologischen Problem."

[114] Ach: Ueber das Denken und das Temperament.

It is doubtful as to how much we can build on such a tenuous basis. In a study of personality we cannot be satisfied with the observation of one or two traits and these gained mainly from introspection. We want to get at all the personal determinants possible by testing the individual not only as to determination, but as to every mode of reaction we can think of. Even the sort of imagery one uses is a valuable partial index, as MARTIN has shown in her recent address.[115] It is only then that the facts could be collated, and undoubtedly some correlation will come to light. It is this very correlation that we are seeking. For as THORNDIKE remarks

> "A statement of the differences between one whole man and another would be an almost interminable inventory of particular differences, unless some traits were so related that knowledge of the amount of one of them possessed by a man informed us of the amount he possessed of the other also"[116]

Why should we expect to find correlation between traits and tendencies? The answer is: common observation puts us on this track. The very classification of people according to the four types of temperament bears evidence of a universal feeling, from the time of antiquity, that a given personality takes a more or less definite direction. This view stood the test of the critical philosophy, for KANT appears to have held the ancient classification in a modified form,[117] and WUNDT adopts a similar scheme. We may question the adequacy of the ancient classification or its amended form, but the possibility of some sort of classification cannot be denied. In the first place, it is a practical necessity. We are constantly judging our fellow-men as individuals without taking into account all their traits. Perhaps five minutes of conversation will be sufficient to give us an impression. What we are in need of is the standardization of these judgments. But secondly, it stands to reason that a number of traits might have a common factor at their root. Thus a person who talks slowly and deliberately is apt to differ from the quick individual in everything involving their constitutional differences that are responsible for the divergence in the rate of their speaking. This would presuppose a limited number of personal determinants, and biologically, a limited number of unit characters with innumerable permutations and combinations.

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[115] Lillien J. Martin: Personality as Revealed by the Content of Images. (Address of the retiring vice-president before the meeting of the American Psychological Association 1916).

[116] THORNDIKE: Educational Psychology, vol. III, p. 348.

[117] WUNDT: Grundzuege der Physiologischen Psychologie, vol. III, p. 637. 5th ed.

THORNDIKE, in his eagerness to show men nearly equal and to give the vast majority of them a modicum of everything so that they may all be mediocre, fails to distinguish in his treatment of individual differences between intelligence traits and personality (character and temperament) traits, with the result that he is thinking in terms of the former and is applying his conclusions promiscuously.

Thus, we can follow him when he says

> "Mental traits are certainly not as a rule unit characters, each of two or three cooperating unit characters. On the contrary, most of them seem to be the results of very many unit characters,"[118]

only if he is referring to an intelligence trait. Certainly a trait like the rate of learning, for instance, is dependent upon very many factors, but when we turn our attention to temperamental traits, the situation is different. Here, on the contrary, we should be inclined to reduce the number of unit characters, because several tendencies might easily owe their origin to the same unit character.

Individual differences have hitherto been treated as the loose appendages of an experiment. They formed a side-issue, but no more. Even when two traits, say two abilities, were being correlated, the emphasis would be not on the individual, but on the abilities that were being examined. Most investigations take up the question of individual differences arising out of the experiment. They simply cannot be ignored now-a-days, but in very few cases do these individual differences appear as more than *disjecta membra.* That is especially true of temperamental differences. If only a suggestion along these lines, made in one investigation, were followed up in other and subsequent investigations, a large body of data would accumulate that would point definitely in one direction or another. Gradually these suggestions would either develop into facts or else they would be thrown overboard.[119]

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[118] THORNDIKE, loc. cit., p. 268.

To illustrate: in 1873, EXNER was led to the conclusion that

> "Man im allgemeinen bei solchen Individuen die kürzeste Reactionszeit zu finden erwarten darf, welche am meisten gewohnt sind, ihre Aufmerksamkeit auf einen Gegenstand zu concentriren, und dass solche Leute, welche ihre Vorstellungen ungehemmt ablaufen zu lassen gewohnt sind, grössere Reactionszeiten haben."[120]

In 1913, LANGFELD was led to the conclusion that those

> "who trusted most to a non-represented determining tendency did the best" [work in passing a stylus down a groove] saying further,
>
> "This suggests why a certain type of mind is unskilled in movement, that is the imaginative type which is continually thinking of other associated things. As there are more of the imaginative among the intellectual, it is not surprising that there is more skill among the non-intellectual."[121]

Surely this is a sufficiently important point for consideration in reaction experiments of any kind.

Worse still is the lack of cooperation or communion among the members of the laboratory with the special purpose in view of studying and correlating individual differences. Instead of a connected chain we get only a large number of links that are never put together, because one experimenter does not know the details of the investigations carried on by other experimenters in the same laboratory.

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[119] Cf. W. STERN's reflections on the subject in his "Differentielle Psychologie," chap. VII. (Arbeitsgemeinschaft und Sammelforschung).

[120] Exner: Untersuchung d. Einfachsten Psychischen Prozesse. Archiv. für die Gesamte Physiologie (Pflueger), vol. VII, 1873, p. 614.

[121] Langfeld: Voluntary Movement under Positive and Negative Instruction. Psych. Review, vol. XX, 1913, p. 477.

There are only one or two other investigations accessible to the present writer in this respect, i.e., with references to a number of subjects that had also taken part in the research under discussion. In one by H. T. Moore,[122] all the subjects he employed, excepting the present writer, were also employed as subjects in our own research, but seeing that the field is so remote from the one we are concerned with, we can hardly expect to find any possible connection between the results of the various individuals. And yet, it may seem curious, there is the fact that his very consonant subjects were our very slow subjects, while the two that appear in the dissonant group were among the very quickest reagents in our experiment; the most dissonant was actually the one who turned out the greatest number of reactions, though a great many were wrong. Now all this may be merely a coincidence, but there is no harm in taking note of coincidences.

In the other research, that by H. E. Burtt,[123] the relation is much closer to our work; and we feel that it is no coincidence when two of his subjects who seem most susceptible to distraction are the slowest reagents, or rather, as has been already explained, are most affected by the interference conditions of our experiment. More than that, the subject who "showed the effect of the distraction most markedly" is the subject who would have by far the highest inhibition coefficient under conditions of interference. Furthermore, in the imagery experiment he displays a "fear of making a mistake"; in our experiment he shows the least tendency to reverse the association and make mistakes that way.

It so "happens" too that this subject is of a decidedly visual type, while the other who keeps company with him is, to all appearances, visual also, though not in so pronounced a way as the former. Both of these subjects never mentioned the occurrence of kinaesthetic imagery while engaged in our investigation.

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[122] H. T. Moore: The Genetic Aspect of Consonance and Dissonance. Psychological Review, Monograph Supplements, vol. XVII, 1914.

[123] H. E. Burtt: Factors which Influence the Arousal of Primary Visual Image, American Journal of Psychology, vol. XXVII, 1916.

From the foregoing it is possible to infer that the decidedly visual type is more susceptible to distraction, interference conditions and the like; and if we turn to another experimental report on an allied subject,[124] we shall find, as one of the results, that the most visual of three subjects who participated in that particular investigation was delayed most in sorting cards under the distraction of reading aloud.

Are we to regard all these relations as coincidences, merely due to chance? Or shall we take them up as beginnings for further study and analysis? From a methodological point of view there can hardly be two opinions on that matter; and anyone who shuts his eyes to such relations or correlations displays a certain narrowness that is, alas, rampant in experimental psychology and proves an obstacle in the way of proper interpretation of the facts. If we are to get all that is to be gotten out of our results, we must make them a stepping-stone for further research. They should have an arrowhead tacked on to them, so that we might be able to orient ourselves with respect to other investigations and problems in related fields. Hence the experimentalist must be possessed of a sense of direction.

A serious drawback in the study of individual differences and their correlation is the complexity of factors that we are confronted with. Many investigators probably feel as if they would never be able to disentangle the numerous threads that may be involved in a single result. Take the instances that we have cited—and here we have a relatively simple situation: How shall we explain, discarding the view that it is a coincidence, the relation between belonging to the visual type of imagery and being susceptible to distraction, or between either of these and slowness under interference conditions and all the other traits that go with it (complete inhibition, undulation, lack of reversals and mistakes, etc.)? Is the type of imagery directly responsible for these other modes of reaction, or is there some common factor giving rise to both the former and the latter, that is to say, the connection would have to be sought farther back in the nervous make-up of the individuals? To answer such questions at the present stage of our knowledge would be a premature venture. We must be patient in regard to this point just as in scores of others.

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[124] M. F. Washburn and M. McMein: The Effect of Mental Type on the Interference of Motor Habits. American Journal of Psychology, vol. XX, 1909, p. 284.

But of what advantage—it will be asked—is it then to talk of such indefinite terms as dominant determining tendencies and personal determinants? Why add to our already increasingly burdensome and unwieldy terminology? Our reply is that these terms, though *structurally* indefinite, are fraught with a very definite meaning functionally. Their value is of a *heuristic* kind. They, at least, pave the way for a solution in indicating what turn we are to take.

In employing such terms as determining tendencies and personal determinants, we are, like the mathematician, *dealing with unknown quantities.* Now X, Y, and Z, may stand for any quantity, to begin with; yet they have a definite relation in the equation, which works out correctly after proper arrangement of the various terms. Is this not precisely the method we are adopting in psychology? First we must have all our terms at our disposal. We then place them in their proper positions by bringing one fact into relation with another. A great many irrelevant data will be dropped, and probably a solid core will remain which it shall then be our task to reduce to a structural category or to translate into physiological language.

The reason why we have chosen to classify determining tendencies into three different classes should be quite plain. They were introduced because there was a real demand for them. We do not believe all determining tendencies equal because, in the first place, there seems to be a *leitmotif* operating universally, which largely shapes the course of the ordinary determining tendencies—those touched off by the experimenter's instructions. But further the fact that each subject has his own way of doing things (difference of degree and combination, *vide supra*) proves that the determining tendencies set into play by the instructions are also modified by other tendencies, varying with the individual, which we, on that account, dubbed personal determinants.

Applying the above relation in the concrete, we have the following state of affairs taking place in our experiment. The subject, in accordance with the instructions, proceeds to depress the one key twice for the red stimulus and to depress the other key twice for the green stimulus. But the dominant tendency to take the course of least exertion will affect his work in such a way that he will emphasize the easier movement and slur the more difficult one, while his personal determinants will direct his mode of reaction in a more specific way,[125] which will vary from that of another individual. If X, Y and Z are represented as the dominant determining tendency, the determining tendencies, and the personal determinants, respectively, then we may express the relation of Y as a function of X and Z, or in symbolic form, $Y = \int (X, Z)$.

The term "physiological cortical set" has had a wide vogue of late in psychology. The concept is a useful one, and though it can scarcely be considered an adequate explanation of the determining tendency, it serves to bring us closer towards some tentative theory. If we accept the "cortical set" as the physiological equivalent of the determining tendency touched off by the instructions, we must remember to take our previous conclusion into consideration. This demands that we make the set dependent upon other prior arrangements which are the physiological equivalents of the dominant determining tendencies and personal determinants.

But why assume such a thing as personal determinants, in the first place? Can individual differences not be explained on the principle of different constellations of determining tendencies? No, that would be a circular procedure, because the determining tendencies do not operate until the instructions have been given to the subject. Now, how is it that one particular constellation should form and not another, unless we suppose that in the individual there is a something which determines that formation and not another?

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[125] Cf. in this connection G. V. Hamilton's "Specific Organic Properties" or reactive tendencies in Sexual Tendencies in Monkeys. Journal of Animal Behavior, IV, 1914, p. 314 ff., especially p. 317.

We fully admit that the working of these different tendencies can, at most, be only a matter of conjecture at present; but, at any rate, it is far better to be in the trial stage than to ignore the problem entirely, by attributing a given mode of reaction to mere chance. In the former case we can at least hope to find a solution some day; in the latter, we cannot so much as make a start.

CHAPTER IX.

APPLICATIONS.

A. Results as Applied to Pedagogy and Education.

Although our problem is predominantly of theoretical significance, it would be worth while to draw a few inferences from the results with regard to such an important subject as education.

Naturally these inferences cannot be amplified so as to be brought into relation with the more typically educational topics such as memory, association and imagination. But for that very reason, i.e., just because these topics have been discussed over and over again, it would be proper to turn our attention to some more neglected points perhaps that suggest themselves as corollaries from our experimental findings.

In the first place, there is one result that is of special interest which was merely alluded to in the chapter on objective results. It was brought out incidentally and has no direct bearing upon the conflict of impulses. We can now discuss it at length because in connection with education it is quite in place.

Upon presenting the stimuli-lists both in an ascending and a descending rate of speed, varying the order in alternate weeks, it was observed that the subjects were almost equally divided as to their preference. Some would much rather have the close dots first and end up with those farther apart, while others preferred it the other way i.e., they wanted to begin with the farther apart dots first and gradually work up to the thicker part of the list. Not only were they decided about their preference, but the very question as to their preference seemed to them unnecessary. The former thought it of greater advantage to *everybody* to start with a dash and then slowly relax, while of the latter, two or three took the trouble of explaining in their introspection that it was the most natural way of doing things to start slowly and gradually keep increasing the speed. The objective results all confirmed the subjective preferences. It may be said that only two subjects were not consistent in their preferences at the time. They seemed to be on the borderland and were subject probably to other variables that did not make so much difference with the rest.

To begin with, the *prima facie* fact of this division would clearly indicate the existence of individual differences with regard to performing a task. Some prefer to take a quick plunge into their work and enjoy the relief that is theirs, as the demand on them becomes diminishingly small; and it is in that way that they can do a better job. Others, however—and probably these are in the majority—must work their way up. They grow with their task.

Now all this is very true, and if we take the trouble to look around we shall find these two types everywhere. But that isn't where the matter ends. It was discovered later that the more difficult the rate was made by increasing the speed, the less prone were any of the subjects to prefer the rapid-slow lists. Not only was such a preference not marked by the previous consistency on the part of three subjects, but in some cases the latter had still stuck to their old statements about their preference while the objective results indicated that better work had been done in the slow-rapid list, whether it came first or second in the sitting. Also those who had previously been borderland cases, were now veering around to join the slow-rapid preference group.

As this observation was only a side-issue, it was not tested out thoroughly by reducing the rate for the other subjects who had preferred the slow-rapid lists from the very start. Nevertheless considering that those who made up the rapid-slow group were the quickest reagents, while the group preferring the opposite order of rates was composed of the slowest reagents, with the originally inconsistent group coming in between, we appear to have a clue to the whole situation; and it seems we can safely venture to offer the following formulation: When the task is difficult, to begin with, and becomes increasingly difficult, it is best to work up one's way gradually in order to obtain the best results. On the other hand, if a task is easy, to begin with, and is steadily becoming easier, the best way to go about it is to tackle the more difficult end first and then gradually relax.

It is true that not all tasks allow of such treatment, but we can conceive of a great many that do and besides the principle may apply to a whole day's work in which a number of tasks are included.

It applies equally well in the matter of education. First, in regard to individual education, each one knows what subject or phase of subject is for him easier as compared with another subject. If he has, let us say, four or five subjects to review among which he finds two easy and two difficult, he ought to begin with the latter. But suppose he has a different proposition before him—this time not a review, but entirely new and difficult work, it would then be of advantage if he could start with something easier and switch off to the more exacting job later. Naturally the question of fatigue enters in here, and it is not necessary that he reserve such work to the very end, when he is worn out. This is, however, a matter to be judged and decided upon by the individual himself in accordance with the special conditions and circumstances that may be involved. The main point is that he is to avoid plunging into the very thick of the difficulty until he has had time to adjust and readjust himself, otherwise his impetus will receive a rebuff that will only impair his efficiency for the rest of the period, so that it does not increase *pari passu* with the growing facility of his task.

Second, as regards the planning and arranging of the school curriculum, we have in the foregoing rule a good guide as to what subjects the session should begin with. Much would, of course, depend upon the grade and age of the children, the period of the year and other such factors. We realize also that the school curriculum is not something that is amenable to frequent changes in conformity with varying conditions. There is also the consideration to reckon with that some children are more adapted to one thing than others, and that it would not be feasible to divide a class on the basis of such inclinations or preferences. Yet, for all that, though we may be doubtful as to whether the study of a foreign language is more difficult than mathematics, or the reverse, there is no denying that certain subjects make a universal appeal to the pupils and call for less effort on their part. All things considered, it seems reasonable that, let us say, a history lesson would be more appropriate to open the session with than an exercise in Latin composition or an explanation of the binomial theorem. When in doubt as to the *relative* degree of ease and difficulty of the various subjects, so as to allow the application of our previously formulated principle, we should be inclined to think that it is safer to follow the easy-difficult instead of the difficult-easy path. As a matter of fact in many schools, a method such as this is adopted in the lower grades where singing or drawing is the first subject of the curriculum, but so far as the writer knows, no evidence has been presented to prove that such a plan is either justified or is only arbitrary.

These suggestions, it must be remembered, are put forward merely in a tentative way. The question of the order of ease and difficulty is, it seems, important enough, and yet it has been entirely ignored so far. In our present work, it forms only an incidental adjunct. It can scarcely be doubted that an investigation, begun along this line, would yield some clear-cut results.

2. In line with the preceding observation concerning the easy-difficult and difficult-easy preferences is the result, both introspective and objective, that after an inhibitory break in the reactions, the situation is, as a rule, regained by starting on the easier of the two movements, and the subject actually waits until a stimulus comes up which represents that movement. The conclusions that may be drawn from this are almost too obvious to require any expatiation. The class review before embarking on a new line of thought, the summary of a chapter before starting on a new topic strikes us as putting into effect a variation of the above result. With the teacher and the writer, the stepping-stone is a precautionary measure in order to avoid a break and confusion; in our work it served as a first aid after the accident has happened. Those teachers who allow their pupils to flounder in their inability to grapple with an elaborate and complex line

of thought rather than take one or two steps backwards to make the transition clear have evidently no insight into the details of their profession.

3. The emphasis that is here laid on gradual adaptation should not be extended too widely; for as we have seen our principle works in both directions and needs careful adjustment which is more practicable in the case of self-application than in applying it to others, especially when these are young children. By no means are the suggestions contained here to be interpreted as calling for an extremely easy plan of study or the setting of very slight tasks. Against this we are warned by another result which shows that if you make a task too easy, mistakes will occur just where they are least expected, thus proving that the loss of the feeling of responsibility and the particular set that goes with it is disproportionate to the degree of ease. A certain modicum of difficulty should attend every task.[126] The ways in which this object can be attained are many and will be ascertainable only after examining the particular situation. The difficulty may be increased sometimes by shortening the period within which the task must be completed, or by introducing some additional work, or even by surrounding the task with a halo of gravity, first as to the *idea involved,* second as to the *consequences entailed* in the event of failure, i.e., the method employed might be that of *exhortation* which would appeal to the better type of mind, and *warning* to those who must have other motives to guide them.

It seems somewhat strange, at the first flush, to think that ease or difficulty could be increased or reduced by such a seemingly artificial method, but the reason for such an attitude would be the sore want of analysis of the terms "easy" and "difficult." So far as the writer is aware no attempt had ever been made to distinguish between subjective difficulty and objective difficulty. The confusion that this results in can be seen from the fact that in English and French investigations, more stress is laid on the objective connotation of the terms, while the Germans often convert our easy and difficult into *"bequem"* and *"unbequem."*

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[126] Cf. Colvin: The Learning Process pp. 283-292.

In reality, as the term is employed ordinarily, many elements contribute to making a thing difficult, the *consciousness of its difficulty* not being one of the least. There is an old story which goes back to the "Once upon a time age" that proves how much insight some possibly untutored mind displayed in that connection.

The story relates of a king who had proclaimed throughout his kingdom that he wanted a tiny hole bored through several very small diamonds in his possession, and that he who would be successful would rise to the height of glory, but any one who undertook this piece of work and happened to break the diamond would be punished by decapitation. A few of the most expert diamond cutters in that land risked their necks with fatal results to themselves. Then one diamond cutter conceived a happy idea. He daringly asked for the last diamond and commissioned one of his apprentices to perform the momentous operation, telling him that he must be very careful, as it was a costly affair. The apprentice accomplished the task successfully. The moral that the story was calculated to bring out is obviously that the high-strung attitude of the master diamond-cutters made it impossible for them to achieve their object. For them the task became too difficult with the grave condition placed on it. For the apprentice, however, the degree of difficulty did not exceed the limit that would impair his efficiency, because his astute master knew just how far to carry the instructions and what responsibility to attach to the situation in the presence of the workingman. We may well imagine that if he had treated the matter too lightly, the last diamond would have been broken too.

Many people fail because they overestimate the difficulty of their undertaking, making it thereby more difficult because they have added from within a new and serious complication. Others again fail because they underestimate the difficulty they have to grapple with, and thus they cannot meet all the conditions that may arise unexpectedly in a given situation. Happy is the man who can so adjust his sliding-scale of energy as to avoid both extremes, for his shall be success.

4. The relativity of the degree of ease or difficulty as affected

by different *Aufgaben* is another corollary of our results that is likely to be of use in problems of practical education, if actually worked out systematically and amply tested. In the course of the preliminary experiments, when instead of presenting the stimuli at different intervals, different rates of speed were given for the same list, it became apparent that a 40 sec. list preceded by a 25 sec. list was easier to do than the same list either preceded by a 50 sec. list or given at the beginning without any preliminary list. The writer did not follow up this relativity phenomenon, seeing that it is only a side-issue with no direct bearing on the main problem, hence the suggestion comes only as a result of a few sporadic cases, but we cannot help noting it both because of its far-reaching application, if demonstrated, and, further, the comparative ease with which it may be tested on a large scale.

If verified, it would mean that if we are innervated for something that is altogether beyond us to accomplish, this effort, while useless so far as the infeasible task is concerned, will be of considerable service in tackling afterwards a less difficult piece of work, but yet, more difficult than usual. On this score, may it not pay then to set and sacrifice an *artificial* task that is too exacting in order to attempt another difficult task with greater alacrity than would otherwise have been the case? It seems that the prevalent habit of setting oneself a schedule that is consistently beyond the particular individual's capacity to keep up with is grounded in the principle that has just been suggested.

The question whether it is advisable to carry out such a plan in ordinary school teaching is a delicate one. It would certainly require a great deal of nicety and judiciousness on the part of the teacher to manipulate such a method; for though it might make things easier for the *average* pupil, it would tend, however, to lower the estimate of the teacher in the eyes of the pupils and to render them refractory, if he or she kept continually assigning burdensome work to them, only to make a considerable remission after a few minutes of consternation in the class-room. Perhaps the best results are to be looked for in the case of self-imposed tasks.[127]

5. The retroactive inhibition of determining tendencies is another result the discussion of which will not be commensurate with its importance as applied to training. We have seen that according to this law, the determining tendencies weakened in a descending order of their specificity, i.e., the most specific determining tendency was the first to become suspended during inhibition, while the most general determining tendency was the last to be arrested during such a state, a phenomenon which puts us in mind of retrograde amnesia.

Now since the instructions or suggestions are the external conditions for these determining tendencies which are mediated through problem ideas, it goes without saying that it is the *most specific instruction that needs the closest attention and greatest stress.* Once the strength of the most specialized determining tendency is insured, the rest follows automatically, since every determining tendency, in coming into play, operates at the same time all those below it in specificity.

This does not mean merely that specialized work requires more practice than unspecialized, but that the amount of practice necessary is out of all proportion to their ratio of elaborateness. In other words, training should not end when it is carried to the *knowing* point, but must be continued till the *emergency* point. *It is the emergency that is the criterion of the strength of the determining tendency.* Only if it can stand the test there, has its hold been firmly fixed. This is a point the significance of which has not been universally grasped, though as a working principle it has been recognized from observation and experience in many quarters.

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[127] If this fact should be confirmed after further experimentation, it would furnish us with the complementary phase of MEUMANN'S Leistungsgesetz des Willens. The explanation of the process is partially contained in this statement: "Unter den Einfluss der Vorstellung einer grösseren Aufgabe spannen wir ohne bewusste Reflexion und ohne die bestimmte Absicht unsere Kräfte mehr an, als wenn uns eine geringere Aufgabe vorschwebt" (Vorlesungen, Vol. III p. 103, 2nd ed.) cf. also the important corollary as applied to education. loc. cit. p. 104.

Let us now turn to the individual differences and see what we can learn from the results appearing under that caption. We have seen that the subjects fall into distinct reactive types. There are the omitters and the confusers—subjects whose mistakes are those of omissions and subjects who, in addition to omitting, also make mistakes of commission, but then their output is much greater than that of the simple omitters. There are also what for want of a better name, we might call the *"undulators"* because they emphasize certain groups and leave gaps in others and the *"equalizers"* because they make an attempt at every group of stimuli, without completing it.

The question now arises whether we can put this result to the same use in educational psychology as the discovery of imaginal types. From an examination of the functional significance of the sensory process and the motor process, we must come to the conclusion that the two are incomparable. The aim of the sensory process is to gain *impressions;* that of the motor process is to give *expression.* Our individual imaginal tendencies can often be made serviceable in different ways according to the requirements of the thing we are trying to learn, but where such adjustment is not attainable, the individuals representing different types need not be exhorted to try to change their mode of learning by an effort to cultivate a different type of imagery.[128] We all recognize, of course, that there is a distinct advantage in being able to put all types of imagery into play, but ought the predominantly audile strive to become more of a visile? Ought the man with a great play of visual images seek to imbibe knowledge by making use of kinaesthesis? Considering that the end can be attained through any one of these media, it might be only a waste of energy to try to learn auditorily what might be done just as well visually, especially as there are so very few who can be said to employ one type of imagery to the exclusion of all other types.[129]

[128] In fact MEUMANN points out that there is more loss than gain in the attempt to cultivate another type of imagery than the one that a given individual is endowed with, and cites his own case as an illustration. cf. MEUMANN: Vorlesungen, Vol. II. p. 547, 2nd ed.

[129] J. R. ANGELL: Methods for the Determination of Mental Imagery,

It is different, however, with the motor process where in the first place, it is more *desirable* to be able to control one's mode of reaction, and secondly, it is more practicable in this sphere.

Since the two pairs of reaction types are mutually incompatible, it is clear that you cannot obtain the same result by following either mode of a pair. If speed is aimed at, the omitter will fail lamentably, while if accuracy is the goal, the confuser will find his work counting for very little. In our experiments either omitting or confusing largely had to take place, owing to the conditions imposed by the method. Mention may also be made of a more or less balanced type in which a compromise is shown between the two extremes. For the same reason, it was not possible both to attempt every group and to complete it, with the result that the subjects fell into these different classes revealing a tendency to emphasize this or that mode of reaction.

Now that we know that such different types exist with pronounced dispositions to react in one way or another, it behooves us to classify subjects (children) on such a basis and to promote greater adaptability in accordance with the purpose of the task. And for this reason it may be pointed out that in dealing with scholars we ought to take these differences into consideration, i.e., to make allowance for them. At the same time, we must try to remedy the lopsidedness by developing a sense of proportion that could be applied in every particular case. The boy who thinks only of filling so many examination books and does not pay so much attention to the details of his answers will find himself hampered in the end, but so will the boy who spends a great deal of time on details fall short of success. He who can carefully balance both factors will, other things equal, take the lead.

Psychological Review, Monograph Supplements, vol. XIII, p. 82; also M. R. FERNALD: The diagnosis of Mental Imagery, Psychological Review, Monograph Supplements, vol. XIV, p. 130. More emphatically THORNDIKE: Educational Psychology, vol. III, p. 381 ff.

COLVIN and MYERS (Development of Imagination, Psychological Review, Monograph Supplements, vol. XI) seem to have reached the conclusion that our imagery changes as our ideas become more abstract and that we grow out of our visual imagery to a large extent.

Can such a transition be effected? Is it possible to adapt one's mode of response? The following illustration from personal experience will probably serve to answer this question.

The writer had been in the habit all through his primary and secondary education invariably to emphasize the first few questions of an examination paper at the expense of the others, nearly always omitting the last with a remark to the effect that the time is up. It was assumed that the examiner would be able to judge in what sort of manner the last question would be answered, if the examination period were extended. Now some examiners do actually make allowance for such pressure, but this is by no means a universal attitude on the part of examiners; and those who are skeptically inclined or who overemphasize brevity will naturally discountenance such a view, because in their opinion, the student should accept the instructions implied in the make-up of an examination paper—literally.

It was not till the beginning of his graduate work that the soundness of such a view suggested itself to the writer and he began cultivating a tendency for distributing his work to meet the time requirement, until the two opposed tendencies nearly balanced each other.

Examples of this sort may be multiplied, and undoubtedly similar adaptations are taking place constantly, but matters would be much facilitated if we could pick out the different motor types out of a class of pupils early in life for special guidance along this line.

B. Application to Ethics

It may seem somewhat out of place to introduce in an experimental essay some observations bearing directly on ethics, but just because such is the case, does it seem desirable to deviate from the conventional method even at the risk of eliciting a shrug of the shoulders from both ethicists and experimental psychologists.

It is a fact but too patent that psychology is deliberately steering clear of all contact with ethics, with the result that ethical writers who start out with a normative scheme in their mind will be apt to apply this normative method to psychological phenomena as well. We can scarcely pick up a text book of ethics without coming across a number of sections dealing with what is often called the psychological prolegomena of ethics. Such terms as desire, volition, motive, intention, wish, decision, deliberation and a score of others of that kind are discussed at great length, and with good reason, for as LADD remarks,

"Ethics, so far as it can be rendered scientific is one of the sciences. Hence its dependence upon psychology and anthropology is to a certain extent absolute."[130]

The treatment of these terms is, however, highly speculative; and, in the main, we are given access to an account of what *should* be the case rather than what actually takes place. Since, however, psychological states and physiological activities are not constrained to fit into any normative scheme we are confronted with the spectacle of formidable systems of ethics being built up on sand-hills. The consequences are that both ethics and psychology are at a disadvantage.

The fault lies with both sides. For the moralist claims that ethics, in dealing with its subject matter has a viewpoint and method of its own; while psychology, at the present day, totally ignores the exigencies of a sister discipline and prefers to remain on safe ground, thus giving an opportunity to ethical writers of soaring high up in the clouds where no resistance is offered to the *logically* (and sometimes illogically) conceived facts about certain mental states.

The chasm must be bridged, if ethics is to be regarded as a science, and if psychology is to guard its own interests. It is, therefore, incumbent upon every experimentalist in psychology, when opportunity arises, to do his share towards clearing up general misconceptions, just as it is the solemn duty of every ethical writer to take into consideration the results of experimental psychology and not to rely merely on an account that is both antiquated and highly speculative. For ethics to ignore the findings of psychology in regard to certain mental states the understanding of which is essential for any ethical theory would be comparable with the situation where psychology should take no account of the work done in physiology or where physiologists should totally disregard the facts established in chemistry and physics.

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[130] LADD: The Philosophy of Conduct, p. 32.

It is not often that an experimental result lends itself to extension into another sphere such as ethics, but since we can perceive the possibility of such an application in the present study, we shall not lay ourselves open to the charge that we are not practising what we preach.

In one of the early chapters of this book, it has been intimated that while our investigation on the conflict of impulses does not include the subject of ethical choice, it does, however, suggest a certain connection between the two problems. STOUT as we have seen, concedes that disconnected impulses interfere with one another in a quasi-mechanical [!] way, but denies this as regards deliberative action. This sharp demarcation-line, drawn between two types of volitional activity opens up a fundamental issue; for it leads us to believe that an ethical situation is *toto coelo* different from an experimental situation, to the extent that a principle involved in the results of the one would work just the opposite way in bringing about a given result in the other.

We have, in the course of our experiments, obtained as our most general result the fact that, in the event of interference, we proceed along the lines of least resistance, that is to say, we choose more frequently the easier of two movements. Can we reasonably expect this to be the case when interfering impulses become conflicting motives towards action? Judging from STOUT's view of the matter, we cannot; and, so far as the writer is aware, that seems to be the prevailing sentiment in ethical circles at least. STOUT quotes with approval a passage from JAMES, which is here reproduced in part.

> "We *feel,* in all hard cases of volition, as if the line taken, when the rarer and more ideal motives prevail, were the line of greater resistance, and as if the line of coarser motivation were the more pervious and easy one, even at the very moment when we refuse to follow it. He who under the surgeon's knife represses cries of pain, or he who exposes himself to social obloquy for duty's sake feels as if he were following the line of greater temporary resistance."[131]

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[131] JAMES: Principles of Psychology, vol. II, p. 548, quoted in Stout's Manual of Psychology, p. 717 (3rd ed).

Stout adds afterwards

> "There can be no doubt that Professor James here describes the facts accurately,"

but he fails to take note of another passage by the same author, in which much light is shed on that *feeling,* and which would, in a large measure, prove that the contrary is true. Here we find James saying

> "We are, I think, misled into supposing that effort is more frequent than it is, by the fact that *during deliberation* we so often have a feeling of how great an effort it would take to make a decision *now.* Later after the decision has made itself with ease, we recollect this and erroneously suppose the effort also to have been made then."[132]

Have we not the clue to the whole situation in these two sentences, and may not this analysis be applied in every case of deliberative action? Does not the underscoring of the word "feel" in the passage quoted by Stout instantly put us in mind of the solution James had offered previously of the problem? To our mind, the emphasis on the word "feel" implies that *phenomenologically* the view is true enough, just as *phenomenologically* we are *free to will,* but as a matter of fact, this phenomenal situation explains nothing. As a basis for exhortation in matters of conduct it may be of some use with a certain class of people, but if our aim is to connect our data in such a way as to be able to explain them, we find ourselves at sea on the adoption of such a doctrine as Stout champions.

It is true that James does not seem to be decided on this whole matter, and he is not at great pains to conceal his ethical bias,[133] but since we are beginning to realize more and more that the course of psychology cannot be steered by ethical motives, we must insist on psychological facts being settled without the aid of ethical considerations.

To the popular mind, virtue is associated with the difficult course of action. Of course the belief is universal that it is easier to yield to a temptation than to resist it, but this belief cannot be accepted as it stands. It requires further analysis. If it means that the average man or woman more frequently goes astray than not, then the view is certainly not a correct one. What is at the root of this belief is the fact that all people find it easier to yield to a temptation at times than *never* to give way to one. That is an entirely different story. The important point, however, is that whether we yield or not, we are *following the lines of least resistance.* Such a conclusion does not seem compatible with the conventional view of morality. One might object that it is putting the hero and the coward, the saint and the moral reprobate on a par. We ask: How else can it be psychologically? The hero is actuated by *his* idea just as the coward is determined by his. What distinguishes their mode of behavior is the judgment of value that attaches to each of their ideas respectively. That difference in significance, however, takes us into another sphere entirely. It is no longer a psychological fact but an axiological datum.

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[132] James, loc. cit. pp. 534-535.

[133] Cf. what he says about freedom loc. cit. vol. II, p. 573. "The present writer does this for the alternative of freedom, but since the grounds of his opinion are ethical rather than psychological, etc. . . . ."

JAMES is inclined to judge the situation from the popular point of view which is only one-sided and anything but critical. Thus we are told

> "He [the virtuous man] speaks of conquering and overcoming his impulses and temptations. But the sluggard, the drunkard, the coward, never talk of their conduct in that way, or say they resist their energy, overcome their sobriety, conquer their courage, and so forth."[134]

Now it doesn't take much acumen to perceive that behind this phrasing there lurks a *petitio principii.* Given the terms sluggard, energy, drunkard and sobriety, coward and courage, we cannot connect these pairs by the verbs *resist, overcome* and *conquer* simply because common usage precludes such a construction. But on the other hand, we can conceive of a case where the hustler overcomes his energy, the teetotaller, his sobriety, and the foolhardy man, his courage. Hence the argument from common parlance (a form of the *argumentum ad populum*) does not take us very far, and might as well be ruled out of court; for the psychological process corresponding to "resisting," "overcoming" or "conquering" does not favor the laudable impulse any more than the culpable one. It is we, *as judging conduct,* who have decided to couple the words bearing a connotation of effort with the acts expressive of virtuous conduct, because we have been accustomed to associate virtuous conduct with the feeling of effort, to begin with. And JAMES himself has already partially explained, as we have seen, the genesis of this association. Probably this association has been reinforced also by education and other sociological factors (religious lore, moralist propaganda).

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[134] Loc. cit. vol. II, p. 548.

Now let us take the very illustration adduced by JAMES and examine it in a psychological light. What happens when the hero or the martyr suffers for duty's sake? There are two courses open to him, and yet he chooses the most difficult one, we say. Yes, but his statement must be qualified by adding the further clause, "From our point of view as judging spectators and from the agent's point of view prior to his becoming an agent." At the moment he actually made his decision, he *acted in the line of least resistance.* Suppose the impulse to cry out under the surgeon's knife were one of the motive ideas and the idea of duty the other, then if the agent did not cry out, it is only because there was less resistance in that direction, that is to say, because the idea of duty was more insistent than the idea which would, under other circumstances, have given vent to a moan. It is similar with the moral reprobate who suddenly becomes converted. Much as the moralist may shy at such a view, it is nevertheless true that the actual conversion follows along the lines of least resistance. The idea that led to the conversion must naturally have been a very powerful agency in order to render the other course (which we naturally think as the easier of the two) more difficult. Why then leave it out of account?

The failure to place the two contesting motive ideas on an equal footing seems to be another case of not seeing the wood for the trees. Duty is such a comprehensive term that often it is lost sight of in the explanation of a moral act. One might suppose that duty, reason, and the like, were not motive ideas or mainsprings of action from the way in which they are systematically eliminated from the determining process. In matters of conduct, this tetragrammaton is often a more potent conjuring-word than the Cabbalistic tetragrammaton. It is not necessary to engage here in a rhapsodical discourse on the potency of duty; but it does seem surprising that those who extol it most are the very ones to overlook its part as a determining idea.

This being the case, it is not to be wondered at when STOUT finds it difficult to square the "greatest resistance" doctrine of ethics with the demands of psychological determinism.

> "If volition is merely the outcome of preceding psychological conditions," he says, *"it must follow the line of least resistance* [italics ours] but in the cases described it follows the line of the greatest resistance. This would seem to imply the intervention of a new factor."[135]

The difficulty is solved by showing that in the cases described, or any others that might be adduced, action is *not* in the line of the greatest resistance, and therefore no new factor is needed.

One might well understand how such a conclusion would militate against the supposed interests of morality. If both moral and immoral conduct follow the line of least resistance, it will be urged, then the ethical man is no more virtuous than the scoundrel. This objection which rests on a naive and conventional view of morality reminds us of SCHILLER's pointed gibe at the austere formalism of KANT's ethical doctrine, when he makes the scrupulous inquirer complain

Gerne dien ich den Freunden, doch thu ich es leider mit Neigung
Und so wurmt es mir oft, dass ich nicht tugendhaft bin,

only to find that the solution, presumably on KANTIAN principles, is

Da ist kein anderer Rath, du musst suchen, sie zu verachten
Und mit Abscheu thun, wie die Pflicht dir gebeut.[136]

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[135] STOUT: loc. cit. p. 718.

[136] SCHILLER, in the series of epigrams known as "Die Philosophen."

The widely-accepted belief is that every act that is not immoral must be a burden; else it would not be regarded as a virtuous act. We should probably all be disposed to agree that "Ehrlich leben ist schwerlich leben," in the sense that it is very rare that one gets along without ever committing an act of dishonesty. But we must remember that the difficulty does not enter into the act proper. What we mean by saying that such a life is difficult is, psychologically speaking, that in cases of temptation, the idea of duty or dignity or that-honesty-is-the-best-policy is with most people, not likely to be always sufficiently vivid to overwhelm the opposing idea. Once, however, that idea does become focal, the act proper, which is interpreted as being honest, issues smoothly out of the idea. The difficulty then does not attach to the act, but to the idea becoming sufficiently vivid.

Hence it follows that all the emphasis must be shifted from the act proper to the antecedent idea or purpose.[187] The aim in ethical education, according to this presentation, is to see that the *desirable idea shall be the effective one.* Herein lies the value of the Aristotelian doctrine of ἕξις. Our problem then is to develop a single comprehensive idea, under which all or nearly all desirable acts can be subsumed, in such a way that it would be uppermost in critical cases, thus smothering the opposing idea.

After all, is this not precisely the course that moralists are taking when they tell us that we must make an effort and that we are then, in consequence of that effort, free to will the proper thing? Is not this exhortation calculated to enliven and reinforce that idea which is to realize the moral act and to smother the propensity idea? Is this not the secret of Kant's regulative Ideas?

The speculative moralist of the old school says

"You must throw off your evil propensities in order to be virtuous."

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[187] *Cf.* in this connection, Holt's remarkable treatment of ethics along the lines of Freudianism and in physiological terms: The Freudian Wish. p. 59 ff.

The scientific moralist puts it this way:

> "If you will regulate your life according to a comprehensive and thoroughly consistent maxim of conduct, no fighting will be necessary, because those evil propensities will be so vague and fleeting even if they do occasionally show themselves, that they will vanish before they can be attended to. The set purpose to resist evil tendencies only serves to throw them into greater relief and to emphasize them."

It goes without saying that, on such a plan, applied ethics is a part of education.

C. Psychological Interference and Efficiency.

In approaching the application of our experiment to industrial efficiency, we may recall the two classes into which the manager of a certain steamship company divided inefficient sea-captains. Some failed because they took so much time to decide on a certain course of action; others proved incompetent because they dashed headlong into the first plan that occurred to them, without gauging the situation as a whole. These two types are obviously not confined to the domain of navigation alone. Those who come in contact with a great many people every day, have the opportunity of observing these contrasts daily. In describing the two opposite types, we may not always employ the same terms on different occasions, yet the ideas meant to be conveyed by these terms are markedly similar. This man, we say, is impetuous or impulsive; another deliberate. Or we differentiate the resolute and the irresolute, or again, in more striking cases, we speak of the one as a DON QUIXOTE and of the other as a HAMLET.

All these pairs, we find, are colored by value references.[138] They are subjective expressions rather than objective descriptions. On the basis of our experiments we should be inclined to call the two types, the dynamogenic[139] and the inhibitive. Such a classification, though primarily suitable to designate the extreme modes of behavior under conditions of interference or other sort of pressure, may, however, be applied generically equally well. Subject LV may be regarded as typical of the dynamogenic tendency, and subjects ZL and SR as characterizing the inhibitive tendency. Both are extremes, and like all extremes, they meet in a certain respect, viz., their unfitness for certain purposes, though they may be highly desirable for others. We may further assume that these two different tendencies, while coming into play in everything expressive of two given individuals, will reach their maximum expression just where the situation is gravest or most delicate. We may not be able to distinguish two individuals with respect to their impulsiveness or hesitancy in ordinary matters, but confronted with a difficulty to be solved in a short time, these people will fall into their proper spheres naturally.

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[138] JASTROW's transparent exposition of the two types is not free from this bias. cf. his Character and Temperament, Chap. VI.

[139] *Dynamogenic* is here used in its etymological sense, and as suggested by the division of PATRIZI who found in connection with (what he regards as) fatigue experiments, that with some subjects, mental activity, carried on during muscular contraction, will lessen the ergographic curve for that period

The application to questions of efficiency resolves itself consequently into two subsidiary problems: (a) What method can we devise, in the interests not only of the employer, but of society at large, in order to detect the degree of a person's susceptibility to interference? (b) How can the individual involved improve his lot by avoiding excesses in either direction? The first problem, it will readily be seen, is of a *diagnostic* character; the second has a *curative* bearing, and involves more directly the persons in question.

As to the diagnostic phase of the problem, MÜNSTERBERG has held out high hope for his situation test[140] as a gauge of ac-

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(type *interferent* ou inhibiteur), with others, it will heighten the curve (type dynamogène); and rarely there occurs an alternation of two modes, cf. M. L. PATRIZI: La simultanéité (Dynamogénie et Inhibition) entre le travail mental et le travail musculaire volontaire unilatéral ou symétrique. Arch. Italiennes de Biologie, LVII, 1912, pp. 176-177.

From an article by Ch. Féré (Mouvements Volontaires, Rev. Philos., XXVIII, 1889, p. 58) it appears that the term dynamogénie had already been in vogue since the appearance of BROWN-SÉQUARD's reserches on inhibition, but that usage corresponds to our "facilitation," i.e., it represents the *absence* of inhibition, but not an *exaggerated* tendency in the opposite direction, such as PATRIZI's usage implies.

[140] Cf. MÜNSTERBERG: Psychology and Industrial Efficiency, p. 86 ff. Also J. W. BRIDGES: An Experimental Study of Decision Types and their correlates. Psychological Review, Monograph Supplements, Vol. XVII, pp. 51-53.

curacy and rapidity in coping with a complex situation. It seems, however, to the writer that the situation test cannot answer the purpose for which it was originally devised, for it is too much of a *static* affair. The subject takes up the card and has to gain an impression of the preponderance of a certain vowel among a large number of miscellaneous letters. He does not, however, feel the *imminence of an impending danger*. The situation is the same at the first second as at the third or fourth second, his action or inaction during the first second being without influence on the situation as a whole. What we miss is the *dynamic* aspect. The switchman or the bridge-tender or the sea-captain has a constantly *changing* situation before him, when the critical moment arrives, which very fact makes a material difference as regards his state of mind and reactions.

In the material used in the present investigation, the dynamic character of the situation is very conspicuous; and it occurs to the writer that, the interference coefficient might be measured by administering tests based on the method employed in the present study. Instead of using two sets of stimuli, the number might be increased to three or four, while the rate might be reduced so as to be within the limit of one's purely motor ability. If the inhibition index alone should be desired, it could be obtained by comparing the motor coefficient (in tapping tests) and the coefficients revealed by the test proper, which would include several factors, the central one, however, being that of interference.

II.

When we come to examine the second question, i.e., how the individual can make the most of a situation by "keeping his head," we see at once that the matter presents many difficulties. In the first place it is necessary to get at the *modus operandi* of inhibition, and before going into the theoretical phase of the subject, let us at this stage only point out that *functionally inhibition means the loss of adjustment*. In a difficult situation we have to keep continually adjusting ourselves to the exigencies of the moment. It does not matter whether we are participating in a smart social function or whether we are called upon to manage a refractory mob or whether we are placed in the position of a sea-captain on a perilous voyage. What is required in all these situations is a quick readjustment perhaps from moment to moment. In some people this readjustment takes place more easily than in others. Interference conditions will affect those persons least. They are the skillful, the dexterous, the adroit, the tactful, the well-poised and self-possessed, in short, the ones who are scarcely ever embarrassed and who seldom show signs of awkwardness. Others, again, who have adjusted themselves for a certain occasion, cannot make the transition to another adjustment so easily. The break is sudden and they stall, or else—and this is true of another class—they readjust themselves badly, that is to say, they fall into a maladjustment by recovering from their condition too soon. They have forced their motor set, and they behave as if they were under the influence of a drug. These are the people who commit a rash act, who in their contempt of embarrassment become forward or rude. They are affected by the complex situation as much as the others are, but in a different way.

What is it that hinders the easy transition from one adjustment to another? The fault, we should venture to say, lies in the excessive amount of imagination and play of ideas that the inhibitive type of individual is subject to. Every novel situation is greeted with a volley of associations which makes one lose his perspective. On account of this imaginative tendency, the motor attitude is not properly set to begin with, but is in a state of instability. Thus the slightest change in the situation would be apt to break the adjustment.

It is evident that the economy of imagination and association is most conducive to easy readjustment. Just enough is to be in consciousness as can be of aid in making the transition from one act to another. All the rest is irrelevant and defeats the end. Thus the speaker, who, when heckled by one of his listeners, attends only to the question and takes up a definite attitude, say of sarcasm, which brings on the desired associations, will probably manage to hold his own and carry his purpose.

On the other hand, however, if he should begin wondering what right his interrupter had to ask the question, or whether he ought to rebuke him or reply in an agreeable tone, the previous adjustment is broken, and the next one must be started all anew.

It is not from the lack of imagination that the inhibited person is at a disadvantage, but rather from the too great flight of imagination. This state is most typical of the adolescent period or the "Backfisch" age; and it seems from various accounts that the keener the intellect the more prone is the boy or girl to present an awkward appearance. In his delightful autobiography of youth,[141] ANATOLE FRANCE tells us of a trivial incident during his school-days that preyed on his mind for months. A woman he had adored, while visiting at his parents' home, had asked him, after playing a nocturne, whether he was fond of music; and all he could answer was "Oui, Monsieur," when what he wished to tell her was that she could draw sighs and sobs, that she could actually draw tears out of the piano. Here was an inhibition evoked by a single glance of the woman that so charmed him. The effect of this inhibition upon him can be seen from the following words

"Puisque la terre ne s'entr'ouvrit pas en ce moment pour m'engloutir, c'est que la nature est indifférente aux voeux les plus ardents des hommes."

Had the young PIERRE NOZIERE (as he calls himself) known at the time of the incident, as he came to realize later, that Madame Gance was only a coquette who could make a fine impression, he would not have made the slip in the first place, and, secondly, he would not have been affected by the slip in the way he was. Yet this same youth who could not get adjusted easily to a social situation felt perfectly at ease in dealing with an intellectual situation. At school, he was self-assertive and displayed a great deal of dexterity in handling delicate questions connected with his studies. His imaginative bent was serviceable there to the utmost, but in the social *milieu* it only distorted the elements of the situation.

The upshot of this is that the curative phase of our problem is fraught with much uncertainty. We have still to learn the psychological *differentiae* of the intellectual, the physical and the social situations. If, for instance, we find that the factor so helpful in the one situation proves to be a disadvantage in another, it will have to be decided first whether we want to curtail the influence of that factor. In a similar connection, JASTROW reminds us that

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[141] Anatole France: Le Livre de Mon Ami XI.

> "It is in part because such persons are peculiarly sensitive that they *are* artists and creative individuals "[142]

the reference being to artists, poets, musicians, writers, inventors, students, the bearers of responsibility.

If there is some doubt as to the *desirability* of such a cure, there is even more misgiving as to its *feasibility*. No one will deny that as we grow in experience, we are apt to handle novel situations in a more matter-of-fact way. With every new experience of a similar sort, the situation becoms less suffused with imagination or non-practical ideas, thus enabling one to take up a practical attitude, that is to say, react upon it objectively; but in our "truth-is-stranger-than-fiction" world, something unusual may turn up at a later date, and he reverts to his old impressionableness. That is what, we might suppose, happens in the case of people intrusted with great responsibility. The captain of a vessel, the railway engineer may have thoroughly inured themselves to their responsible positions, but it is not often that they encounter a real danger. Some day, however, they are suddenly confronted with a grave peril, and then such an idea may occur to them as "To think I am in this position" or "That's frightful" or he may picture to himself the result of the calamity—and the moment he drifts into this affective attitude, he is stunned for action. When he recovers from this state, it is probably too late. That is, of course, on the supposition that the individual in question is of the inhibitive sort.

The transference of training undoubtedly helps us to overcome our susceptibility to inhibition on important occasions, but whether one can completely outgrow an inborn trait like that is a different matter. Mosso[143] may have learnt to address an audience without those symptoms of fear and embarrassment which were noticeable at his first public appearance, and ANATOLE FRANCE, we should suppose, managed to lose his ill-at-easeness when in female society,[144] but, if originally of the inhibitive type of mind, novel social situations would still present more difficulties to them than to the originally self-possessed and adroit individuals. What if Mosso should suddenly espy his king among the audience, or ANATOLE FRANCE should find himself unusually honored by his fellow academicians! We must also remember that age and fame tend to lessen the inhibitive tendency,[145] and, therefore, the average individual given to inhibition is not to be compared with the two men just mentioned in regard to overcoming that tendency.

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[142] JASTROW: Character and Temperament, p. 321.

Such popular injunctions as "Be calm," "Don't feel nervous," etc., etc., are not helpful at all, just because the inhibitive person who is struck with the delicacy of a situation is not master of himself, and cannot control his dulled condition. Again, if he makes up his mind beforehand to treat the situation, no matter how grave or delicate it might be, as a mere trifle, the chances are that he will lapse into the other extreme and do something rash.

Much is to be unravelled and analyzed before we can approach the therapeutic phase of our efficiency problem satisfactorily. We have only gathered up the loose ends of the tangled skein without attempting to take the threads apart, but obviously this must be done first before we can reach a conclusion applicable to the practical side of our investigation.

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[143] Mosso: Fear, pp. 1-4.

[144] "Maintenant, je n'ai pas trop peur de mes contemporains," he says by way of contrast.

[145] ERNST RENAN seems never to have freed himself from this tendency. In his Souvenirs d'Enfance et de Jeunesse, which he wrote at the age of sixty, he says "Ma nullité avec les gens du monde dépasse toute imagination. Je m'embarque, je m'embrouille, je patauge, je m'égare en un tissu d'inepties" (chap. III).

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